Invasive Species Unit 3

Biology and Ecology

Overview

What is the biology behind invasiveness? A species can become invasive when introduced to new ecosystems and/or freed from its natural constraints. Certain qualities can give plants, animals, and insects a competitive edge over other species. Biologists recognize that “weedy” traits might indicate that a plant has the potential to become a pest. Devices and strategies for long-distance travel, such as seeds with propellers or Velcro-like casings, allow plants to invade new areas. Biological characteristics, such as the ability to harness airborne nitrogen or produce millions of seeds, allow plants to dramatically affect the environments they invade. They become “ecosystem engineers,” changing their surroundings in ways that can negatively affect other species.

In addition to invasive species’ own methods of dispersal, globalization has opened the door to rapid transit around the world. A small cluster of insect eggs clinging to the branches of an imported Christmas tree, or a seed packet ordered online can make the trip from Oregon or Central Africa to your front door in record time. What happens when these new organisms arrive in Hawaiʻi? Sometimes they escape into the wild. To effectively respond to these foreign invaders, scientists must investigate where they came from, how they got here, and how to keep them from spreading.

Length of Entire Unit:

10-11 class periods with extended labs

Unit Focus Questions

1) How are unknown plants identified?
2) What is the protocol for creating a plant voucher?
3) How do scientists determine which species are invasive?
4) What is the Weed Risk Assessment and how is it used?
5) What are ecosystem engineers and how do they work?
6) How do invasive organisms travel?
7) What environmental factors influence biological invasions?

Unit at a Glance

Activity #1

Weed Risk Assessment Bingo

Students learn about the weed risk assessment process and rate species' potential "weediness" by playing a game of Bingo.

Length:
One lass period

Prerequisite Activity:
"What Makes a Plant Invasive?" and other activities from "Weed Warriors" Unit 5 in the Rain Forest Module are helpful, but not essential.

Objectives:
- Learn which biological traits contribute to a plant's ability to invade new areas.
- Rate a species' "weediness," using criteria adapted from the Hawaii-Pacific Weed Risk Assessment.
- Distinguish between nonnative and invasive plants in Hawai'i.

Activity #2

Backyard/Schoolyard Survey

Students survey their backyards or schoolyard, recording data either with field notebooks or global positioning system (GPS) units. Students learn which identifying features to look for in the field, the proper protocol for collecting specimen vouchers, and how to make plant presses.

Length:
Two or three class periods, allowing a week in between for specimens to dry

Prerequisite Activity:
None

Objectives:
- Develop basic botany skills: plant identification, specimen collection, and voucher preparation.
- Learn to record meaningful field notes.

Activity #3

Ecosystem Engineers I: Strawberry Guava

Students conduct a lab exploring the effect of strawberry guava bioactive compounds on lettuce seed germination and growth.

Length:
Two class periods with two-week lab

Prerequisite Activity:
None

Objectives:
- Identify how an invasive plant species might alter soil or other habitat conditions to affect the surrounding ecosystem.
- Explore how invasive plants can affect native seedling germination and growth.
- Formulate a hypothesis and conduct a lab to observe the effects of strawberry guava bioactive compounds on lettuce seed germination and growth.
- Create a poster presentation of lab results.

Activity #4

Ecosystem Engineers II: Ironwood

Students conduct a lab exploring the effect of ironweed needle cover on *‘a’ali’i* seed germination and growth.

Length:
Two class periods with six-week lab

Prerequisite Activity:
None

Objectives:
- Identify how an invasive plant species might alter soil or other habitat conditions to affect the surrounding ecosystem.
- Explore how invasive plants can affect native seedling germination and growth.
- Formulate a hypothesis and conduct a lab to observe effects of ironwood needle cover on *‘a’ali’i* seed germination and growth.
- Create a poster presentation of lab results.

Note:
Activities 3-5 are labs exploring the same concept of ecosystem engineering by invasive species. Each lab involves different plants and strategies, but there is considerable overlap. You may want to combine them or choose the one that best fits your needs.

Activity #5
Ecosystem Engineers III: Nitrogen-Fixers

Students design lab exercises to demonstrate how certain plants use bacteria to capture nitrogen from the air.

Length:
Two class periods with two-week lab

Prerequisite Activity:
None

Objectives:
- Identify how an invasive plant species might alter soil or other habitat conditions to affect the surrounding ecosystem.
- Explore how bacteria help certain plants harness airborne nitrogen.
- Formulate a hypothesis and design and conduct a lab to observe nitrogen accumulation in root nodes.
- Create a poster presentation of lab results.

Note:
Activities 3-5 are labs exploring the same concept of ecosystem engineering by invasive species. Each lab involves different plants and strategies, but there is considerable overlap. You may want to combine them or choose the one that best fits your needs.

Activity #6
Wiliwili Gall Wasp Invasion

Students trace the path of the 2005 wiliwili gall wasp invasion on Maui using real-life data and Google Earth technology. They explore the concept of vectors and learn about the significance of the wiliwili tree to the dryland forest ecosystem and the native Hawaiian culture. They devise strategies for stopping the gall wasp's spread.

Length:
One class period

Prerequisite Activity:
None

Objectives:
- Trace the path of the 2005 wiliwili gall wasp invasion on Maui using real-life data and Google Earth technology.
- Identify vectors and pathways that facilitate the spread of invasive species.
- Devise strategies for stopping an invasive pest.
- Predict the efficacy of control strategies, based on existing and plausible environmental factors.

Enrichment Ideas

- Discuss the “weediness” factor of non-native plants that rely on specialist pollinators. Examples include ficus trees (*Ficus macrophyllaor* is one species) that require fig wasps and night blooming cereus (*Hylocereus undatus*), or dragon fruit, that require bats or moths. As long as their pollinators do not arrive in the Islands, these plants are less likely to be invasive. But what happens when the pollinators show up? How should these plants be treated?

Resources for Further Reading and Research

For information about the Hawaii Weed Risk Assessment, official site: www.hpwra.org

Nitrogen Fixing and Native Hawaiian Plants: Tenbruggencate, Jan. “Nitrogen-fixing plants: Self-feeding as a bad thing,” post on Raising Islands blog: http://raisingislands.blogspot.com/2007/08/self-feeding-as-bad-thing.html

Leianuenue Bornhorst, Heidi. *Growing Native Hawaiian Plants: A How-To Guide for the Gardener*, Bess Press, 2005.

Activity #1

Weed Risk Assessment Bingo

Length:
One class period

Prerequisite Activity:
"What Makes a Plant Invasive?" and other activities from "Weed Warriors" Unit 5 in the Rain Forest Module are helpful, but not essential

Objectives:
- Learn which biological traits contribute to a plant's ability to invade new areas.
- Rate a species' "weediness," using criteria adapted from the Hawai'i-Pacific Weed Risk Assessment.
- Distinguish between non-native and invasive plants in Hawai'i.

Vocabulary:

Allergen	Evolve	Tuber
Corm	Invasive	Vegetative fragmentation
Disperse	Nitrogen-fixing	
Ecosystem	Pollinate	

● ● ● Class Period One: *Weed Risk Assessment Bingo*

Materials & Setup

Print enough bingo cards for every student to have one, plus ten or more spares, depending on how many rounds you would like to play.

For each student
- 1 Bingo card pp. 13-71
- 32 Bingo markers (pennies, beans, or other small objects will work)
- Student Page "How to Spot a Potential Plant Pest" pp. 73-75
- Scrap paper

Instructions

1) Pre-assign the Student Page "How to Spot a Potential Plant Pest" as homework or read it in class.

2) Lead a discussion about the weed risk assessment process with your students, using information from the Teacher Background page "The Hawai'i-Pacific Weed Risk Assessment."

3) Tell students that they will be playing a game of bingo based on questions drawn from the

Hawai‘i-Pacific Weed Risk Assessment. Pass out bingo cards and markers. Each card represents a different non-native species found in Hawai‘i. Some, but not all, are invasive.

4) Read the characteristics on the Teacher Background Page “Weedy Characteristics” slowly, one at a time. Students place markers on their cards as the matching characteristics are read. Characteristics have different point values. Some indicate such a high potential for invasiveness that they earn two or five points. Other characteristics indicate a low potential for invasiveness and earn a negative point score. Have students tally their scores separately on a piece of scrap paper. When a student’s card earns 9 points, it’s an invasive pest. He or she yells “pest” and the game pauses. If the card is filled out properly, he or she wins that round.

5) Have the winning student read each characteristic with a marker on it. Discuss with the class why having that characteristic might make a species likely to become invasive.

6) Remove the winning weed card from rotation, replacing it with a spare. (To illustrate the weed’s invasiveness, you can place it in a “quarantine” box.) Have students clear and swap their cards with one another between each round. Play several more rounds, reading the questions in a different order each time. In a final blackout round, the first student to completely fill his or her card wins.

7) Starting with the cards having the most markers and finishing with the cards having the least, review each of the characteristics. Discuss why having a particular suite of characteristics might make a species even more likely to become invasive. Ask how many students did not have nine markers. Plants that score just below nine fall into a gray area: they may or may not be weeds. At present they are not likely to become invasive, but they require further evaluation. Plants with low scores are not weeds. They can be safely planted in Hawai‘i. Ask students to guess the identity of their species. The cards are numbered; match the numbers on the cards to the numbered species.

Journal Ideas

- What characteristics make a plant weedy? What characteristics don't appear to affect weediness? What could be the influence of certain combinations of characteristics? (For instance "bird-dispersed" and "many seeds.")
- Do you think that plants that score high on the Hawai'i-Pacific Weed Risk Assessment should be allowed into Hawai'i? Why or why not? What about plants that score low?
- What are the benefits of using non-weedy species in landscaping and agriculture?
- Name a species that has weedy characteristics but is also considered useful in Hawai'i. Who gains from its use? Who (or what) is negatively impacted by its continued use? Is it possible to mitigate the negative impacts? Who should be responsible for/pay for that mitigation?

Assessment Tools

- Participation in game and discussion
- Journal entries

Teacher Background

Hawai‘i-Pacific Weed Risk Assessment

The purpose of a weed risk assessment is to identify species that are likely to become invasive pests in a given area. This allows consumers, nursery owners, and resource managers to make informed decisions about what non-native plants can be safely imported and planted.

The Hawai‘i-Pacific Weed Risk Assessment (WRA) is a series of forty-nine questions relating to the species' biology, geographic origin, and behavior in Hawai‘i and elsewhere. Biologists consult published scientific records to answer the yes or no questions, which results in a score for each species.

A high score (7 or more*) means the plant poses a high risk of becoming an invasive pest in Hawai‘i and other Pacific Islands. A score of zero or below indicates that the plant is not likely to have major ecological or economic impacts in Hawai‘i or on other Pacific Islands, based on the screening process. Plants that score 1-6 fall in a gray area. More information is needed to determine whether they could have major ecological or economic consequences in Hawai‘i or on other Pacific Islands. The WRA is a proactive reference tool; it has no regulatory function at this time.

Learn more about the WRA:
http://www.botany.hawaii.edu/faculty/daehler/WRA/

*For the purposes of this lesson's game, the score has been adjusted. In the game, plants that score 9 and higher are invasive.

Teacher Background

Weedy Characteristics for Bingo

(The following questions were adapted from the Hawai‘i-Pacific Weed Risk Assessment for the purpose of this game only. They will not provide an accurate score and should not be used outside of the classroom.)

Read to students:
These are some of the questions that biologists use to determine whether or not a plant is likely to be invasive in Hawai‘i. Each bingo card represents a real plant, which may or may not be a weed. As the questions are read, add markers to the matching squares on your card. Some characteristics score more than one point, others score zero points, and some subtract a point. Keep a tally of your score on a piece of scrap paper. If your plant scores nine or more, it's a pest. Yell "pest!"

- Does it have a climbing or smothering growth habit? (Yes = 1) Vines and climbing plants can completely shroud other vegetation, including trees, blocking out sunlight and eventually weakening or killing the underlying plants.

- Does it form dense thickets? (Yes = 1) Plants that grow closely together in dense thickets deprive other vegetation of light, water, and nutrients. They can prevent other plants from growing in an area. Such thick growth also impedes the movement of humans and animals in an area.

- Is it a grass? (Yes = 1) Grasses tend to be very competitive. They are adapted to grow quickly, disperse rapidly, and form thick cover. They may also tolerate grazing or fires that can kill other plants.

- Is it a nitrogen-fixing woody plant? (Yes = 1) Nitrogen-fixing plants (mostly legumes, plants in the pea family) have bacteria in their roots that convert nitrogen from the air into a form that plants can use. Nitrogen is an essential nutrient for all plant growth, and these plants may have a competitive edge with this built-in ability to produce their own fertilizer.

- Does it form underground storage organs, such as corms or tubers? (Yes = 1) Plants store energy in these structures, allowing them to resprout or grow back even after repeated cutting, browsing by animals, fires, or droughts.

- Is it water dispersed? (Yes = 1) Plants with buoyant seeds or plant parts can spread rapidly and invade waterways, rivers, streams, and coastlines.

- Is it wind dispersed? (Yes = 1) Wind-dispersed seeds tend to be small and often have hairs, wings, or other structures that allow them to travel long distances on wind currents. These plants have the ability to invade very remote and isolated areas.

- Is it bird dispersed? (Yes = 1) Bird-dispersed seeds are found in fleshy or pulpy fruits that birds like to eat. Birds swallow the seeds, then deposit them later, after they've flown somewhere new.

Bird-dispersed plants have the ability to spread rapidly far from the original seed source.

- Is it likely to be dispersed by humans? (Yes = 1) Plants that people desire (as food, fuel, or ornamentals) tend to be planted wherever people live, work, or grow crops. This gives plants an added opportunity to invade new areas.

- Does it require specialist pollinators? (Yes = -1) Plants that have specific pollinators, such as hummingbirds, bats, large moths, etc., may not be able to produce seeds in a new area lacking their pollinator. Therefore, requiring specialist pollinators is a handicap, not a weedy advantage.

- Is the species suited to a tropical climate? (Yes = 1) Species suited to a tropical climate will find themselves at home in the Hawaiian Islands.

- What is the quality of climate match? (Medium =1, High =2) Tropical climates can vary. Some are hotter, more humid than Hawai‘i. Plants coming from a climate that closely resembles those found in these Islands will have a good chance of thriving here.

- Does it have broad climate suitability? (Yes = 1) Some plants can invade a variety of climates. They would find many niches on Maui, where diverse ecosystems range from sunny coastline to snow-capped summit.

- Is it an agricultural or forestry weed? (Yes = 2) Some plants compete with valuable farm crops, or forestry plantations, reducing yields and increasing management costs. Others may be unpalatable to cattle or other grazing animals and reduce the quality of pasture. If a plant has been reported as an agricultural or forestry weed elsewhere, it is likely to be one in Hawai‘i.

- Is it an environmental weed? (Yes = 2) Environmental weeds invade natural areas, compete with native species and threaten biodiversity. They can also degrade the functioning of watersheds, increase erosion, and modify soil health. If a plant has been reported as environmental weed elsewhere, it is likely to be one in Hawai‘i.

- Is it a member of the melastome family? (Yes = 1) Many plants in the melastome family have proven themselves to be fast-spreading pests throughout the Pacific. If it’s been recognized as a problem species in similar island environments, it’s likely to be one here.

- Is it aquatic? (Yes = 5) Aquatic plants introduced into new areas almost always become highly invasive. When freed from natural competitors or predators, they often experience “explosive” growth rates and quickly dominate their new habitat.

- Does it produce spines, thorns or burrs? (Yes = 1) Plants armed with these natural defenses can harm or injure humans and animals, and may outcompete plants lacking this protection. Spines, thorns and burrs also make removal or control of the species more difficult, and hazardous.

- Is it an allergen, or toxic to humans? (Yes = 1) Some plants have chemicals or pollen that can cause rashes, severe allergic reactions, sickness, or even death to people that come into contact with or consume them.

- Is it toxic to animals? (Yes = 1) Poisonous plants can harm the health of pets and livestock that accidentally eat or come into contact with them. These plants can thrive even in areas with pressure from grazing animals.

- Is it a fire hazard? (Yes = 1) Certain plants (especially some grasses) increase the risk of fire to both natural and residential areas. They may produce a lot of biomass that easily burns when it dries out, or they may contain highly flammable chemicals in their leaves or sap.

- Is it shade tolerant? (Yes = 1) Plants that tolerate low light levels are often able to invade the understory of intact, native forests and may eventually outcompete native vegetation.

- Does it reproduce by vegetative fragmentation? (Yes = 1) Some plants are able to re-sprout from pieces of stems, roots, and even leaves that either break off or are cut off from the parent plant. This enables them to spread without producing seeds, and makes control or removal of these plants difficult.

- Matures within 1 year? (1 year = 1, more than 1 = 0) Plants that mature in one year or less are able to produce seeds rapidly. They tend to invade new areas and persist in areas much longer than slower growing plants.

- Is it capable of prolific seed production? (Yes =1) When plants produce large numbers of seeds, they increase their ability to take over an area as well as to spread away from the site and invade new areas.

- Does it have a persistent seed bank? (Yes =1) Seeds that remain viable or fertile in the soil for long periods of time are able to germinate years, or decades, after the parent plant is gone. This ability can make removal or eradication of certain plants difficult, if not impossible.

Teacher Background

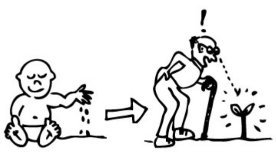
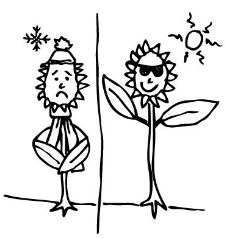
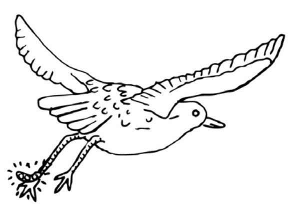
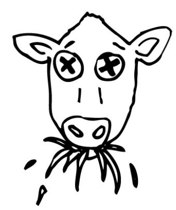
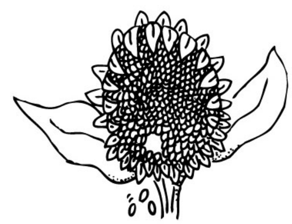
Bingo Card Plant Species (30 unique cards)

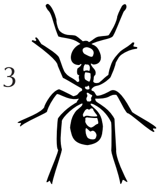
Card #	Common Name	Scientific Name	Number of Points
1.	‘Awa	(*Piper methysticum*)	[7]
2.	Plumeria	(*Plumeria rubra*)	[5]
3.	Banana	(*Musa* sp)	[6]
4.	Hawaiian bamboo	(*Schizostachyum glaucifolium*)	[8]
5.	Miconia	(*Miconia Calvescens*)	[14]
6.	Iron wood	(*Casuarina equisetifolia*)	[15]
7.	Ivy gourd	(*Coccinia grandis*)	[14]
8.	Pampas grass	(*Cortaderia jubata*)	[19*]
9.	Banana poka	(*Passiflora tarminiana*)	[14]
10.	Fountain grass	(*Pennisetum setaceum*)	[16]
11.	Long thorn kiawe	(*Prosopis juliflora*)	[16]
12.	Strawberry guava	(*Psidium cattleianum*)	[13]
13.	Castor bean	(*Ricinus communis*)	[15]
14.	Yellow Himalayan raspberry	(*Rubus ellipticus*)	[15]
15.	Giant salvinia	(*Salvinia molesta*)	[23*]
16.	Christmas berry	(*Schinus terebinthifolius*)	[16]
17.	Fireweed	(*Senecio madagascariensis*)	[15]
18.	Gorse	(*Ulex europaeus*)	[16]
19.	Cane tibouchina	(*Tibouchina herbacea*)	[16]
20.	Mountain apple	(*Szygium malaccense*)	[8]
21.	Shampoo ginger	(*Zingiber zerumbet*)	[6]
22.	Breadfruit	(*Artocarpus altilis*)	[6]
23.	Coconut palm	(*Cocos nucifera*)	[5]
24.	Spider lily	(*Crinum asiaticum*)	[7]
25.	Royal Poinciana	(*Delonix regia*)	[8]
26.	Wattle	(*Acacia mearnsii*)	[15]
27.	Arundo	(*Arundo donax*)	[14]
28.	Cat’s claw	(*Caesalpinia decapetala*)	[16]
29.	Kahili ginger	(*Hedychium gardnerianum*)	[12]
30.	Lantana	(*Lantana camara*)	[15]

*Blackout

Weed Assessment Bingo

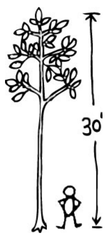
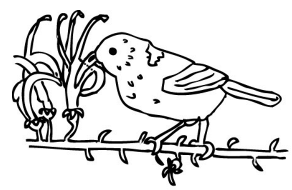
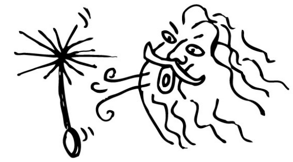
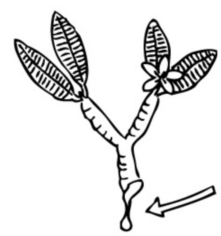
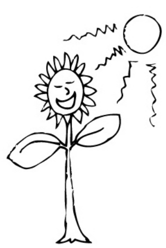
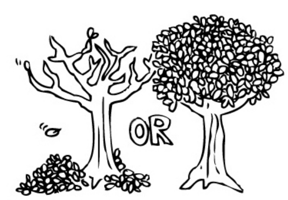
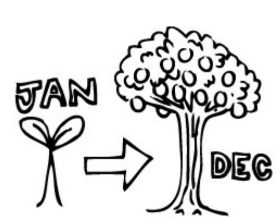
#1

Persistent seed bank 	Environmental weed 	Evergreen 	Grows to 7 feet tall 
Shrub 	Likely to be dis-persed by humans 	Fire hazard 	Native to tropical America & Africa 
Quality of climate match: high 	Bird dispersed 	Toxic to animals 	Prolific seed production 
Species suited to tropical climate 	Agricultural/ Forestry weed 	Forms dense thickets 	Produces spines, thorns or burrs 



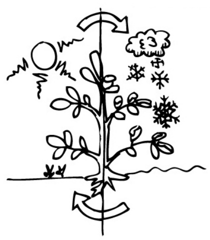
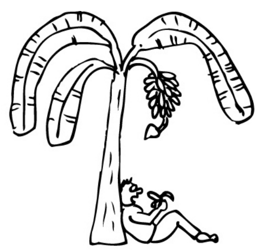
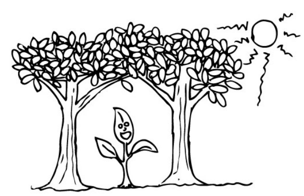
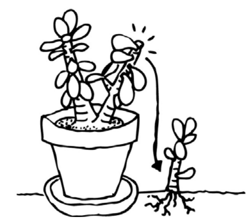
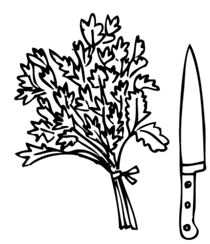
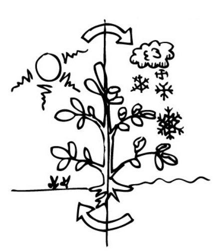
Weed Assessment Bingo

#2

Grows up to 30 feet tall 	Quality of climate match: high 	Requires specialist pollinators 	Wind dispersed 
Species suited to tropical climate 	Tree 	Allergen/toxic to humans 	Produces milky sap 
Requires full sun 	Native to tropical & subtropical Americas 	Likely to be dispersed by humans 	Deciduous & non-deciduous varieties 
Wind tolerant 	Used in lei-making 	Easily propagated 	Matures within 5 years 

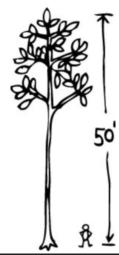
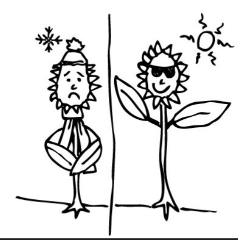
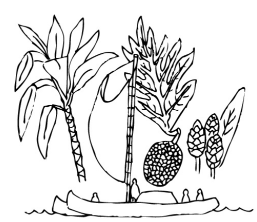
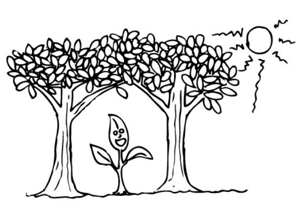
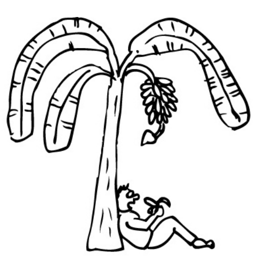
Weed Assessment Bingo

#3

Species suited for tropical climate 	Grows in clumps 	Used in medicine 	Easily propagated 
Perennial 	Edible 	Shade tolerant 	Reproduction by vegetative fragmentation 
Native to Southeast Asia 	Likely to be dispersed by humans 	Herb 	Quality of climate match: high 
Fiberous 	Perennial 	Hawaiian canoe plant 	Large leaves 

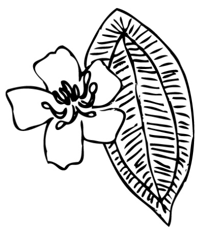
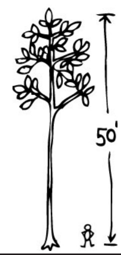
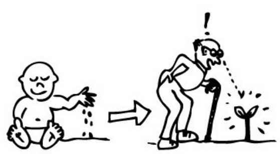
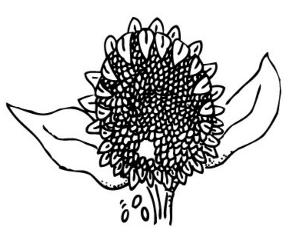
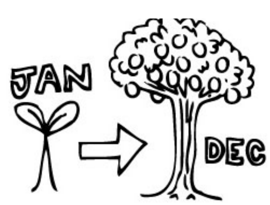
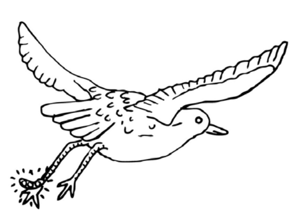
Weed Assessment Bingo

#4

Likely to be dispersed by humans 	Grows up to 50 feet tall 	Broad climate suitability 	Grass 
Evergreen 	Forms dense thickets 	Grows in clumps 	Quality of climate match: high 
Fiberous 	Native to Southeast Asia 	Species suited to tropical climate 	Hawaiian canoe plant 
Shade tolerant 	Edible 	Jointed stems 	Used to make musical instruments 

Weed Assessment Bingo

#5

Member of the Melastome Family 	Grows up to 50 feet tall 	Forms dense thickets 	Species suited to tropical climates 
Persistent seed bank 	Very large, umbrella-like leaves 	Native to Central & South America 	Water dispersed 
Prolific seed production 	Matures within four years 	Quality of climate match: high 	Broad climate suitability 
Likely to be dispersed by humans 	Bird dispersed 	Environmental weed 	Shade tolerant 

Weed Assessment Bingo

#6

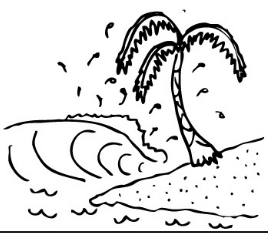
Native to Australia & Southeast Asia

Allergen/Toxic to humans

Broad climate suitability

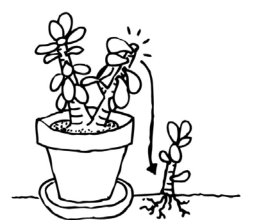
Prolific seed production

Salt tolerant



Likely to be dispersed by humans

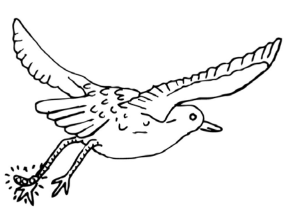
Reproduction by vegetative fragmentation



Fire hazard

Nitrogen-fixing woody plant

Bird dispersed



Environmental weed

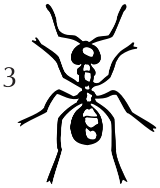
Quality of climate match: high

Water dispersed

Grows to 150 feet tall

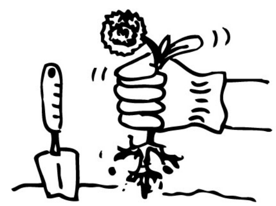
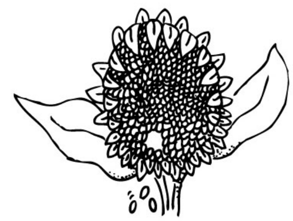
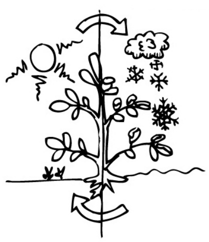
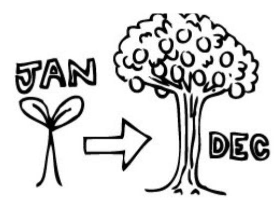
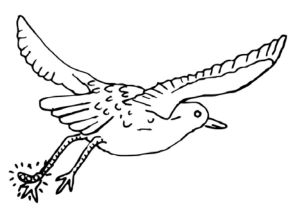
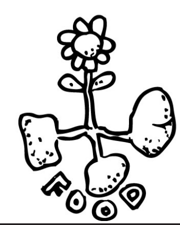
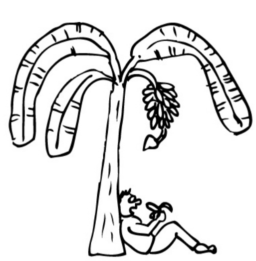
Forms dense thickets

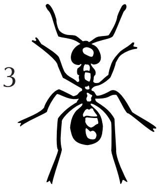
Species suited to tropical climate



Weed Assessment Bingo

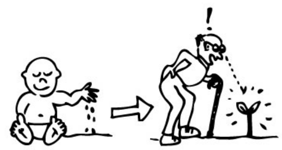
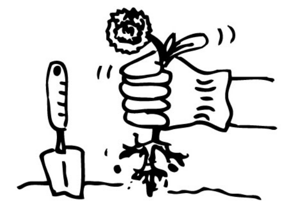
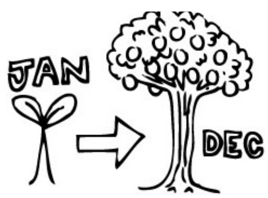
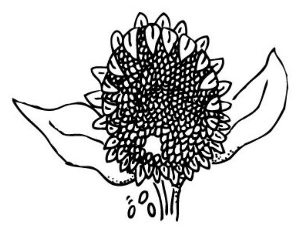
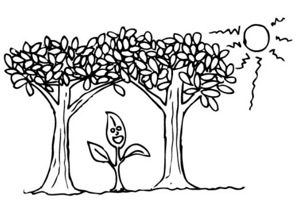
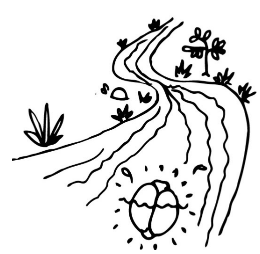
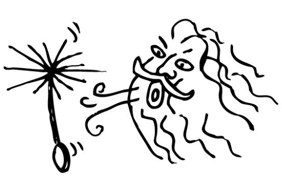
#7

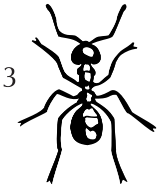
Climbing or smoth-ering growth habit 	Native to Africa, India & Asia 	Agricultural/ Forestry weed 	Prolific seed production 
Perennial 	Vine 	Likely to be dis-persed by humans 	Matures within one year 
Species suited to tropical climate 	Bird dispersed 	Environmental weed 	Forms underground storage organs such as corms or tubers 
Edible 	Reproduction by vegetative fragmentation 	Quality of climate match: high 	Fibrous 



Weed Assessment Bingo

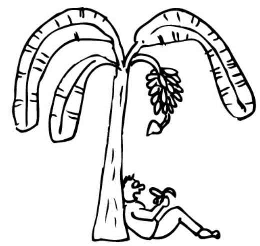
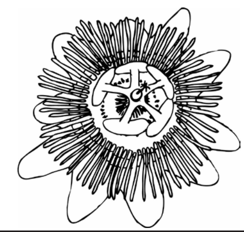
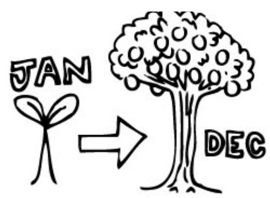
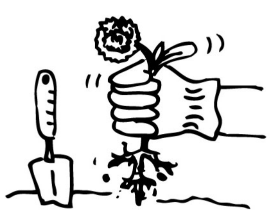
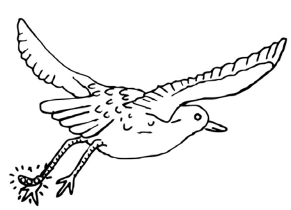
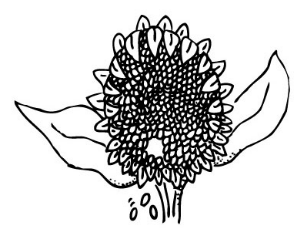
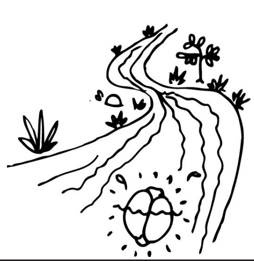
#8

Fire hazard 	Persistent seed bank 	Broad climate suitability 	Agricultural/ Forestry weed 
Likely to be dispersed by humans 	Matures within one year 	Prolific seed production 	Grass 
Shade tolerant 	Water dispersed 	Environmental weed 	Quality of climate match: high 
Wind dispersed 	Species suited to tropical climate 	Forms dense thickets 	Produces spines, thorns or burrs 



Weed Assessment Bingo

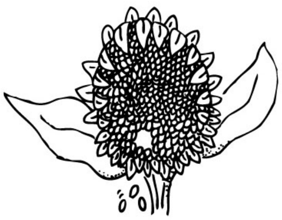
#9

Climbing or smothering growth habit 	Environmental weed 	Edible 	Member of Passiflora family 
Likely to be dispersed by humans 	Matures within one year 	Broad climate suitability 	Shade tolerant 
Agricultural/ Forestry weed 	Bird dispersed 	Prolific seed production 	Quality of climate match: medium 
Water dispersed 	Vine 	Species suited to tropical climate 	Native to South America 

Weed Assessment Bingo

#10

Prolific seed production



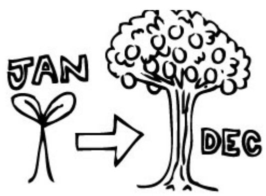
Native to North Africa

Broad climate suitability

Agricultural/ Forestry weed

Likely to be dispersed by humans

Matures within one year

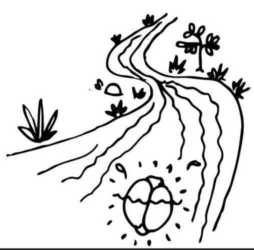


Fire hazard

Grass

Species suited to tropical climate

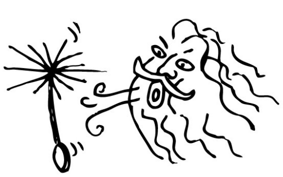
Water dispersed



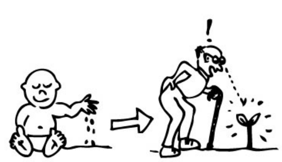
Grows to 3 feet tall

Grows in clumps

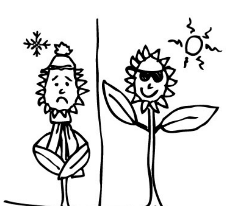
Wind dispersed



Pesistent seed bank



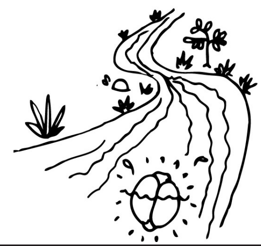
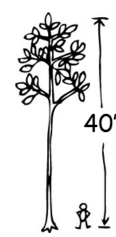
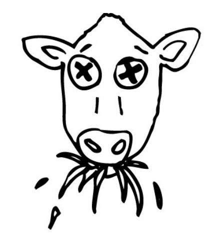
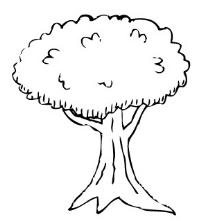
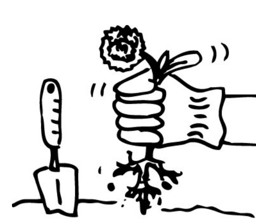
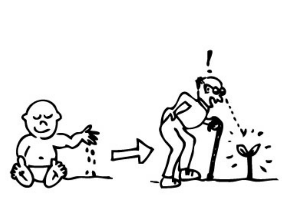
Quality of climate match: high



Environmental weed

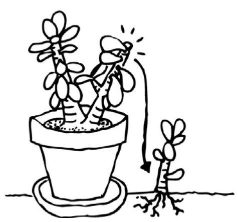
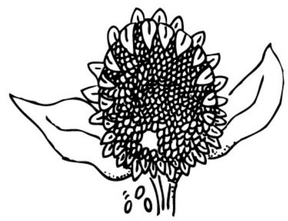
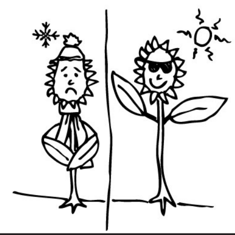
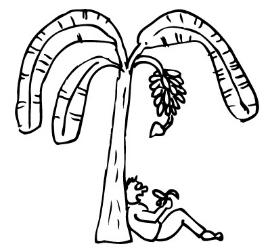
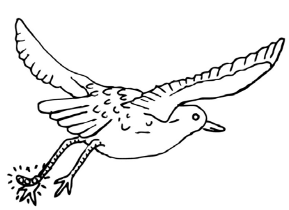
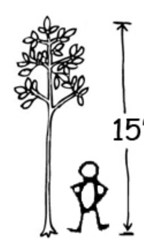
Weed Assessment Bingo

#11

Environmental weed 	Native to Africa 	Water dispersed 	Allergen/Toxic to humans 
Species suited to tropical climate 	Nitrogen-fixing woody plant 	Grows to 40 feet tall 	Toxic to animals 
Likely to be dispersed by humans 	Tree 	Agricultural/ Forestry weed 	Prolific seed production 
Quality of climate match: high 	Persistent seed bank 	Forms dense thickets 	Produces spines, thorns or burrs 

Weed Assessment Bingo

#12

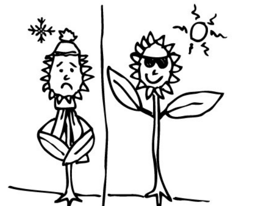
Reproduces by vegetative fragmentation 	Prolific seed production 	Quality of climate match: high 	Edible 
Broad climate suitability 	Likely to be dispersed by humans 	Species suited to tropical climate 	Shade tolerant 
Tree 	Bird dispersed 	Environmental weed 	Native to Brazil 
Used to make wooden crafts 	Persistent seed bank 	Forms dense thickets 	Grows to 15 feet tall 

Weed Assessment Bingo

#13

Species suited to tropical climate

Quality of climate match: high

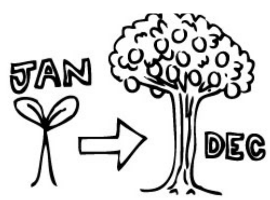


Broad climate suitability

Prolific seed production

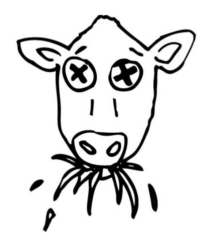
Likely to be dispersed by humans

Matures within one year

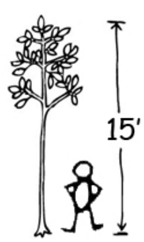


Allergen/Toxic to humans

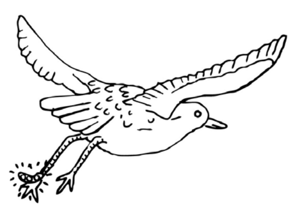
Toxic to animals



Grows to 15 feet tall



Bird dispersed



Environmental weed

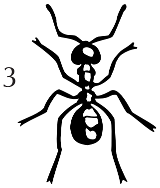
Shrub

Water dispersed

Persistent seed bank

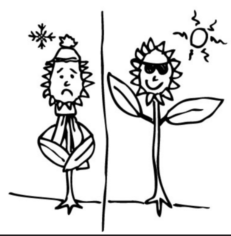
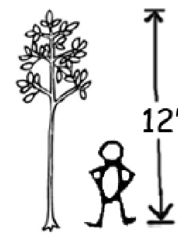
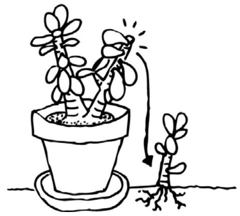
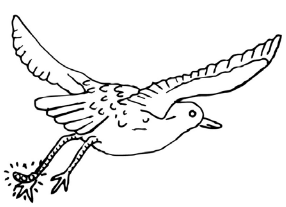
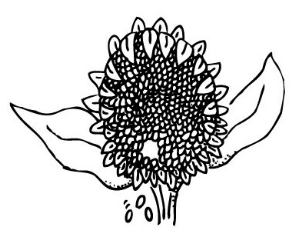
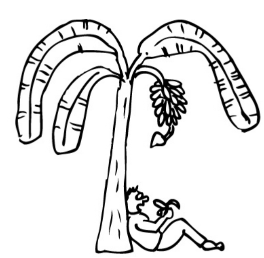
Forms dense thickets

Native to Africa



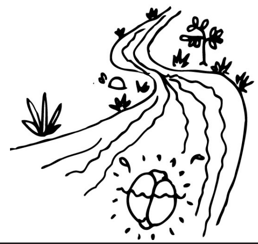
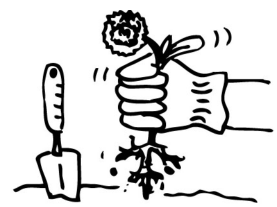
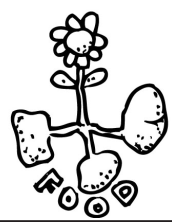
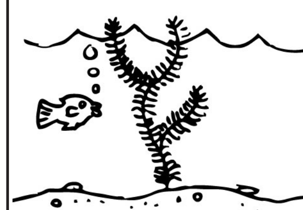
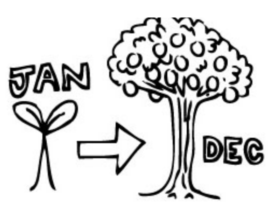
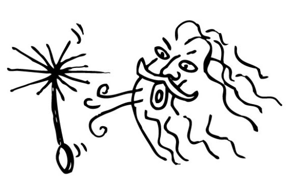
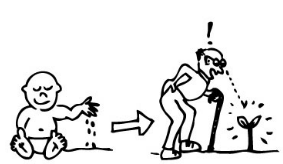
Weed Assessment Bingo

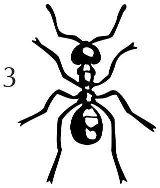
#14

Forms dense thickets 	Quality of climate match: medium 	Broad climate suitability 	Grows to 12 feet tall 
Reproduces by vegetative fragmentation 	Likely to be dispersed by humans 	Nitrogen-fixing woody plant 	Produces spines, thorns or burrs 
Bird dispersed 	Prolific seed production 	Environmental weed 	Shade tolerant 
Agricultral/Forestry weed 	Persistent seed bank 	Native to Southeast Asia 	Edible 

Weed Assessment Bingo

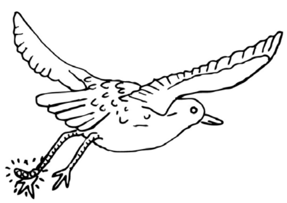
#15

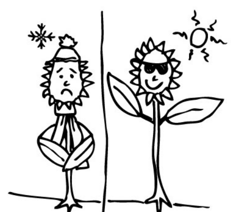
Environmental weed 	Water dispersed 	Agricultural/ Forestry weed 	Quality of climate match: high 
Reproduces by vegetative fragmentation 	Forms underground storage organs such as corms or tubers 	Broad climate suitability 	Aquatic 
Forms dense thickets 	Matures within one year 	Species suited to tropical climate 	Climbing or smoth-ering growth habit 
Wind dispersed 	Persistent seed bank 	Shade tolerant 	Likely to be dis-persed by humans 



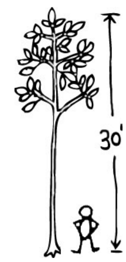
Weed Assessment Bingo

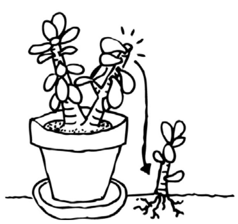
#16

- Bird dispersed


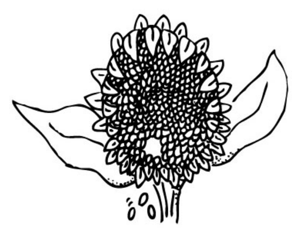
- Quality of climate match: high


- Native to Brazil

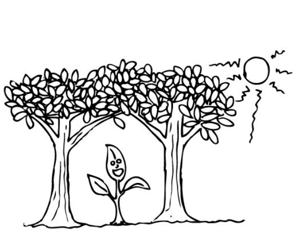

- Grows to 30 feet tall


- Reproduces by vegetative fragmentation


- Likely to be dispersed by humans


- Prolific seed production


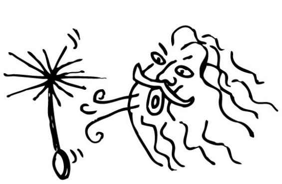
- Allergen/toxic to humans


- Shade tolerant


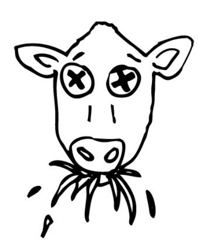
- Species suited to tropical climate


- Environmental weed


- Forms dense thickets


- Wind dispersed


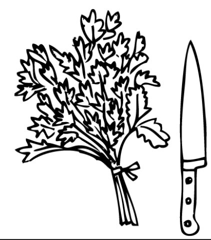
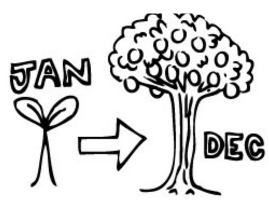
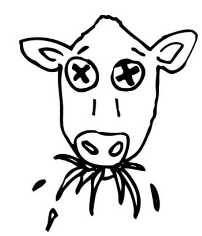
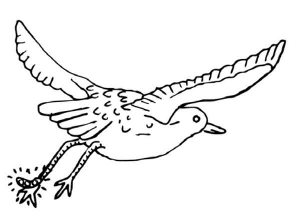
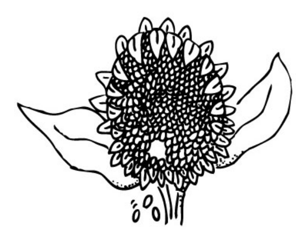
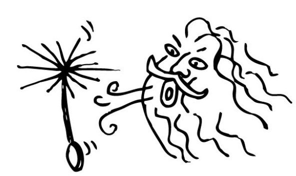
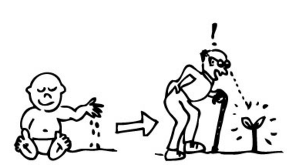
- Tree

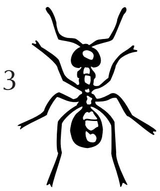

- Toxic to animals


- Agricultural/Forestry weed


Weed Assessment Bingo

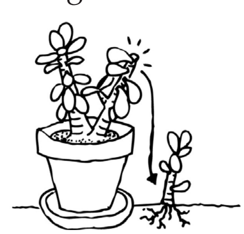
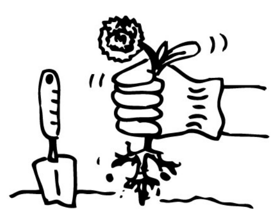
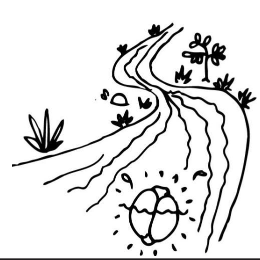
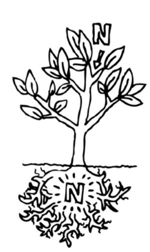
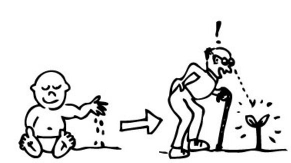
#17

Reproduction by vegetative fragmentation 	Grows to two feet tall 	Herb 	Quality of climate match: high 
Broad climate suitability 	Matures within one year 	Species suited to tropical climate 	Toxic to animals 
Agricultural/ Forestry weed 	Bird dispersed 	Prolific seed production 	Wind dispersed 
Member of the Aster family 	Persistent seed bank 	Native to South Africa 	Environmental weed 



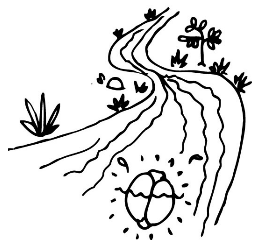
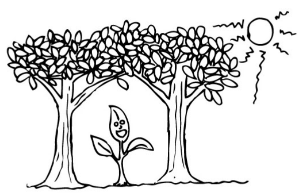
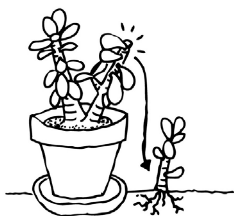
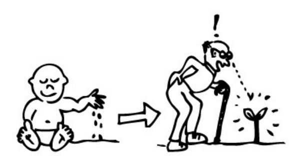
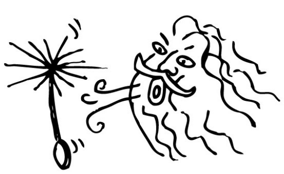
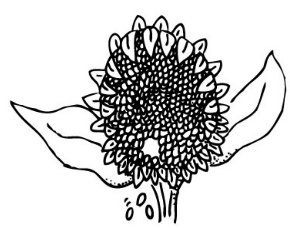
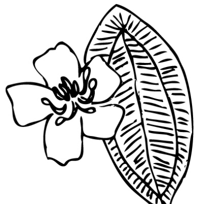
Weed Assessment Bingo

#18

Allergen/Toxic to humans 	Reproduction by vegetative fragmentation 	Broad climate suitability 	Forms dense thickets 
Agricultural/ Forestry week 	Evergreen 	Quality of climate match: high 	Fire hazard 
Likely to be dis-persed by humans 	Water dispersed 	Species suited to tropical climate 	Prolific seed production 
Produces spines, thorns or burrs 	Shrub 	Nitrogen-fixing woody plant 	Persistent seed bank 

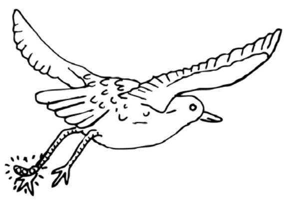
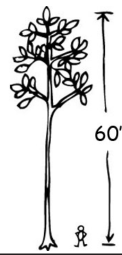
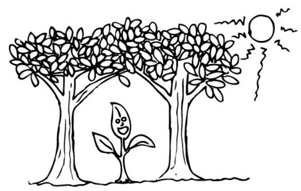
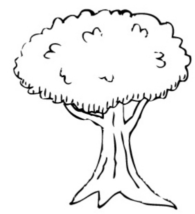
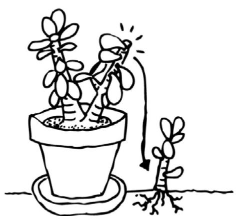
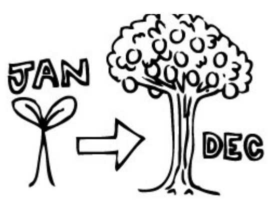
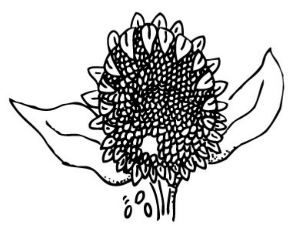
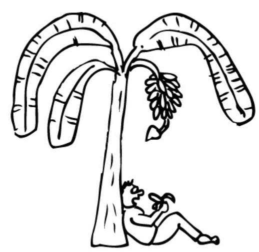
Weed Assessment Bingo

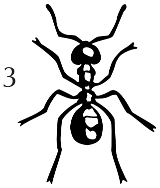
#19

Water dispersed 	Shade tolerant 	Quality of climate match: high 	Species suited to tropical climate 
Reproduces by vegetative fragmentation 	Likely to be dispersed by humans 	Agricultural/ Forestry weed 	Persistent seed bank 
Wind dispersed 	Native to Brazil 	Prolific seed production 	Forms dense thickets 
Member of the Melastome family 	Shrub 	Grows up to six feet tall 	Environmental weed 

Weed Assessment Bingo

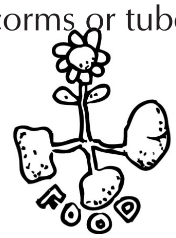
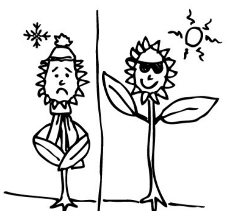
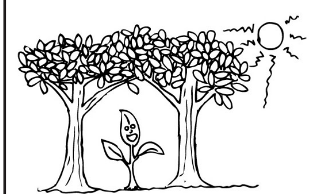
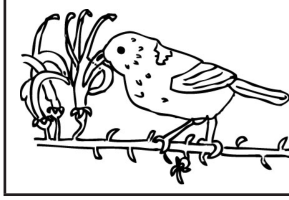
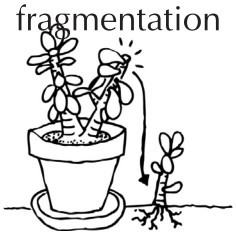
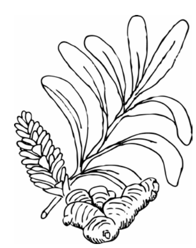
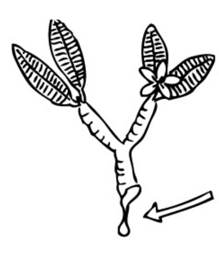
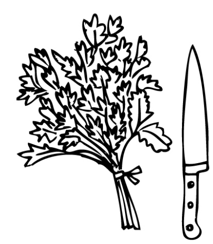
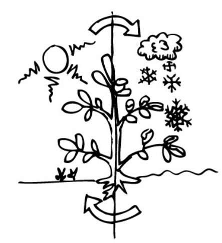
#20

Bird dispersed 	Grows to 60 feet tall  	Shade tolerant 	Tree 
Reproduces by vegetative fragmentation 	Matures within seven years  	Prolific seed production 	Likely to be dis-persed by humans 
Quality of climate match: high 	Belongs to the Myrtle family 	Species suited to tropical climate 	Edible 
Hawaiian canoe plant 	Used in dye 	Native to Malaysia 	Evergreen 



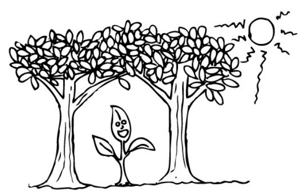
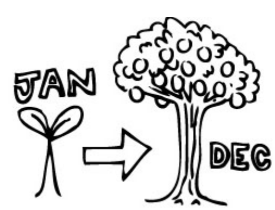
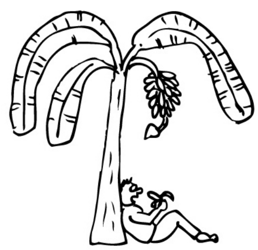
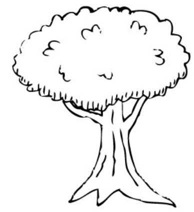
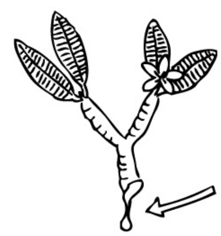
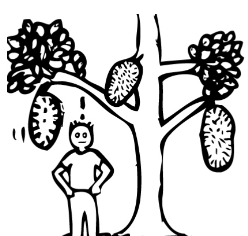
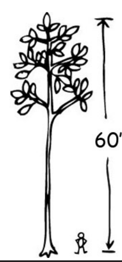
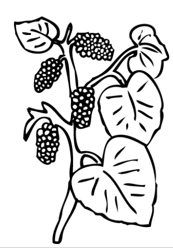
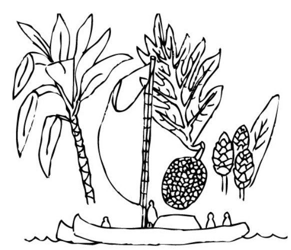
Weed Assessment Bingo

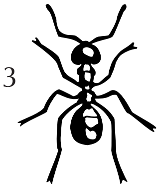
#21

Forms underground storage organs such as corms or tubers 	Quality of climate match: high 	Shade tolerant 	Requires special pollinators 
Reproduces by vegetative fragmentation 	Member of the Ginger family 	Likely to be dispersed by humans 	Grows up to 7 feet tall 
Species suited to tropical climate 	Produces aromatic sap 	Herb 	Perennial 
Native to India 	Easily propagated 	Hawaiian canoe plant 	Understory plant 

Weed Assessment Bingo

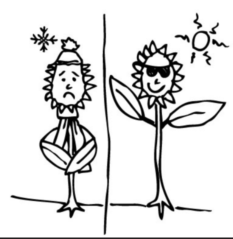
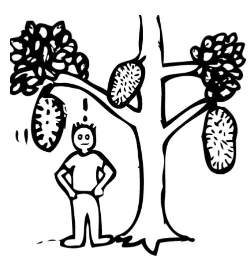
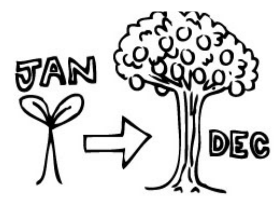
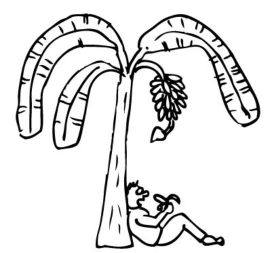
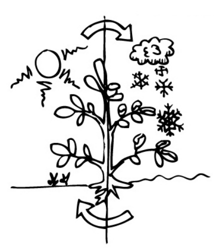
#22

Species suited to tropical climate 	Quality of climate match: high 	Shade tolerant 	Matures within four years 
Edible 	Likely to be dispersed by humans 	Tree 	Produces milky sap 
Large seeds/fruits 	Grows to 60 feet tall 	Belongs to Mulberry family 	Hawaiian canoe plant 
Reproduction by vegetative fragmentation 	Easily propogated 	Native to Polynesia 	Used in medicine 



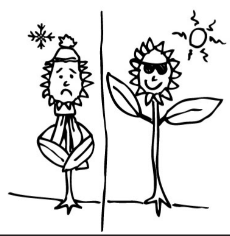
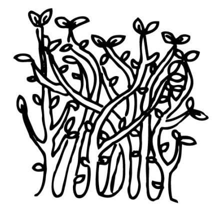
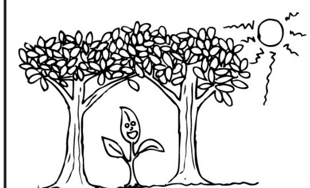
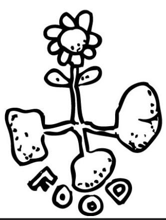
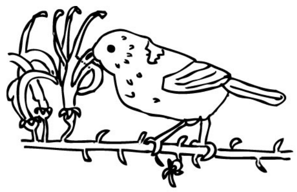
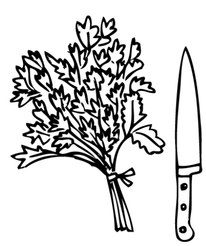
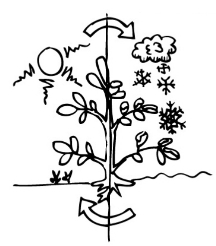
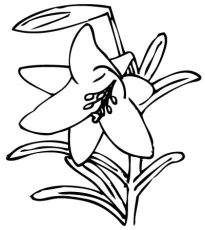
Weed Assessment Bingo

#23

Species suited to tropical climate 	Quality of climate match: high 	Water dispersed 	Likely to be dispersed by humans 
Large seeds/fruits 	Tree 	Matures within six years 	Edible 
Salt tolerant 	Perennial 	Grows to 100 feet tall 	Native to South East Asia and Melanesia 
Large leaves 	Hawaiian canoe plant 	Used for thatching, cordage 	Fibrous 

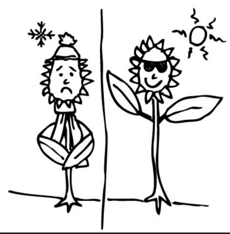
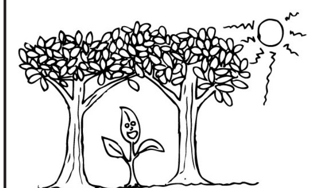
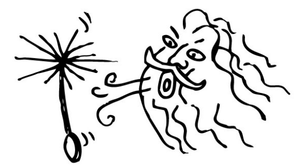
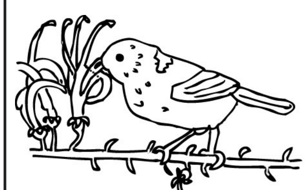
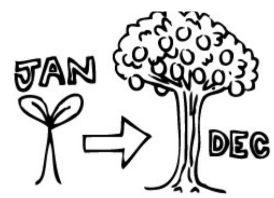
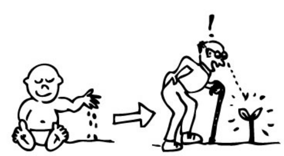
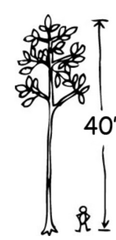
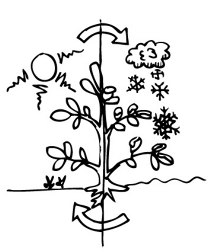
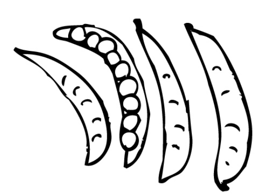
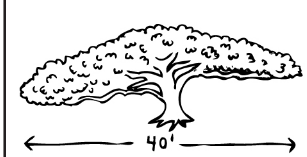
Weed Assessment Bingo

#24

Species suited to tropical climate 	Quality of climate match: high 	Forms dense thickets 	Shade tolerant 
Forms underground storage organs such as corms or tubers 	Requires special pollinators 	Likely to be dis-persed by humans 	Allergen/toxic to humans 
Salt tolerant 	Herb 	Grows up to seven feet tall 	Perennial 
Belongs to the Lily family 	Native to Souteast Asia 	Grows in clumps 	Understory plant 

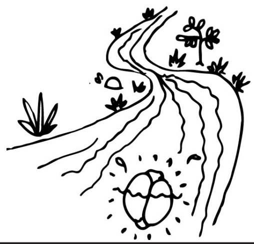
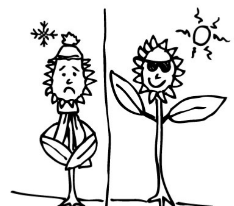
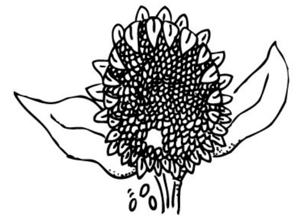
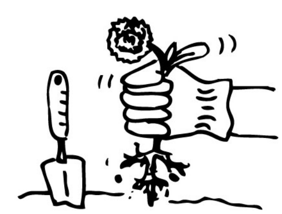
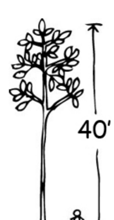
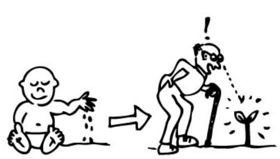
Weed Assessment Bingo

#25

Species suited to tropical climate 	Quality of climate match: high 	Shade tolerant 	Wind dispersed 
Broad climate suitability 	Nitrogen-fixing woody plant 	Requires special pollinators 	Matures within four years 
Likely to be dispersed by humans 	Persistent seed bank 	Tree 	Grows to 40 feet tall 
Perennial 	Native to Madagascar 	Belongs to the Legume family 	Branches can span 40 feet or more 

Weed Assessment Bingo

#26

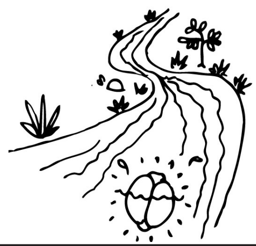
Species suited to tropical climate 	Water dispersed 	Quality of climate match: high 	Prolific seed production 
Broad climate suitability 	Fire hazard 	Nitrogen-fixing woody plant 	Likely to be dispersed by humans 
Tree 	Native to Australia 	Environmental weed 	Agricultural / Forestry weed 
Grows up to 40 feet tall 	Persistent seed bank 	Forms dense thickets 	Belongs to the Legume family 

Weed Assessment Bingo

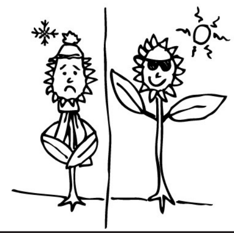
#27

Species suited to tropical climate

Water dispersed

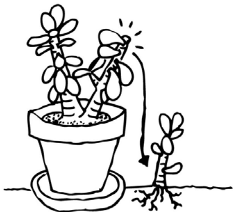


Quality of climate match: high

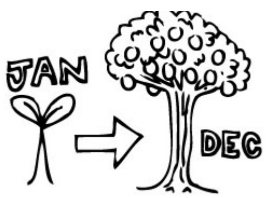


Broad climate suitability

Reproduction by vegetative fragmentation



Matures within one year

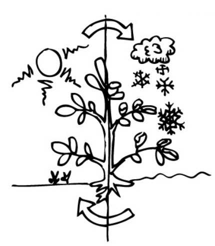


Jointed stems

Fire hazard

Grass

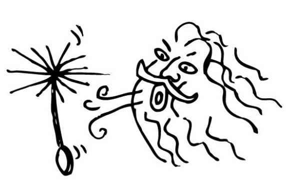
Perennial



Environmental weed

Likely to be dispersed by humans

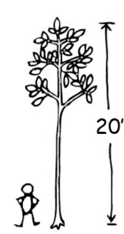
Wind dispersed



Native to Southeast Asia

Forms dense thickets

Grows to 20 feet tall



Weed Assessment Bingo

#28

Likely to be dispersed by humans

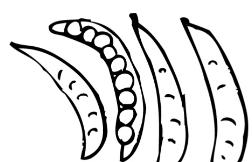
Environmental weed

Climbing or smothering growth habit

Prolific seed production

Broad climate suitability

Belongs to the Legume family

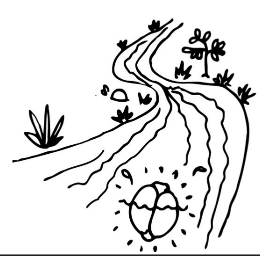


Fire hazard

Nitrogen-fixing woody plant

Quality of climate match: high

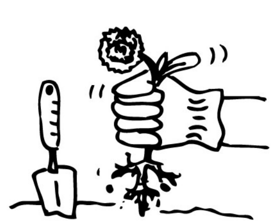
Water dispersed



Native to Southeast Asia

Vine

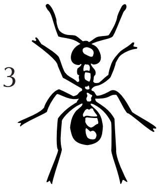
Agricultural / Forestry weed



Species suited to tropical climate

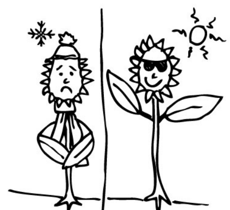
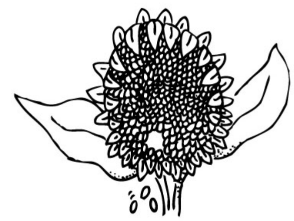
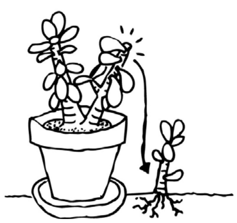
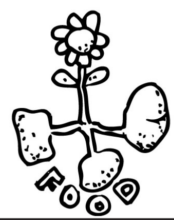
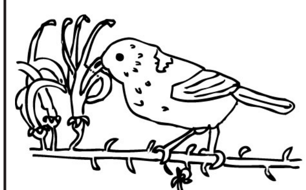
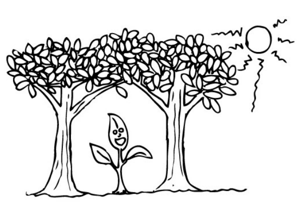
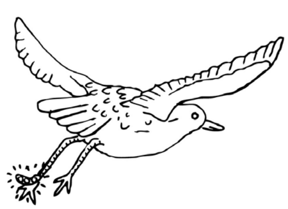
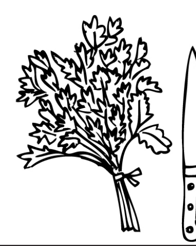
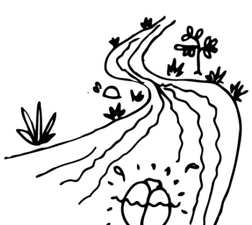
Forms dense thickets

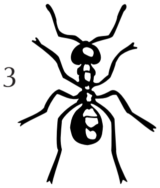
Produces spines, thorns or burrs



Weed Assessment Bingo

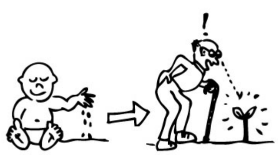
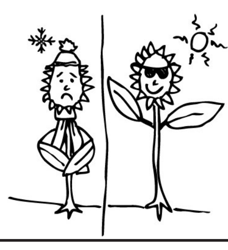
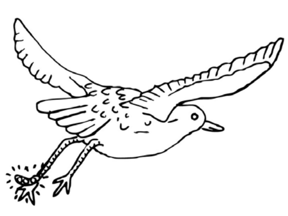
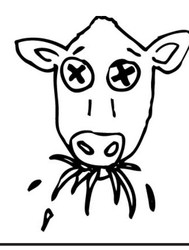
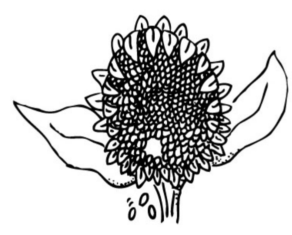
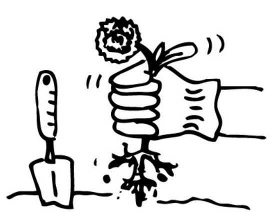
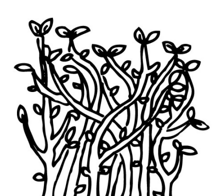
#29

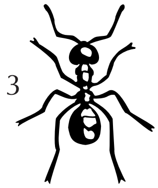
Species suited to tropical climate 	Quality of climate match: high 	Broad climate suitability 	Prolific seed production 
Reproduction by vegetative fragmentation 	Forms underground storage organs such as corms or tubers 	Requires specialist pollinators 	Likely to be dispersed by humans 
Shade tolerant 	Bird dispersed 	Environmental weed 	Herb 
Water dispersed 	Native to India 	Forms dense thickets 	Grows to 6 feet tall 



Weed Assessment Bingo

#30

Persistent seed bank 	Environmental weed 	Evergreen 	Grows to 6 feet tall 
Shrub 	Likely to be dispersed by humans 	Fire hazard 	Native to tropical Americas and Africa 
Quality of climate match: high 	Bird dispersed 	Toxic to animals 	Prolific seed production 
Species suited to tropical climate 	Agricultural / Forestry weed 	Forms dense thickets 	Produces spines, thorns or burrs 



How to Spot a Potential Plant Pest

Oceanic islands are particularly vulnerable to invasion by "alien" (nonnative) plants, animals, insects, and diseases.

Island species evolved in isolation, away from the pressures commonly found on continents. Grazing mammals, predatory ants, many types of diseases, and frequent fires were not part of the natural ecosystem of ancient Hawai'i, so native Hawaiian species did not develop mechanisms to defend themselves from these dangers.

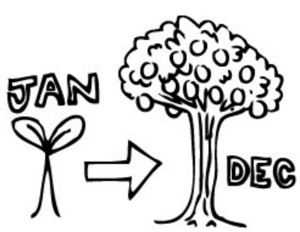
When humans brought these and other plagues to Hawaiian shores, the native species were biologically unprepared. Consequently, many Hawaiian forests have vanished while introduced plant species—especially invasive ones—have taken their place.

The Hawaiian Islands are currently home to thousands of introduced plant species. Scientists consider at least 100 of these nonnative species to be major threats to native Hawaiian ecosystems. Why are some species problematic while others are not? The answer is that some nonnative plants are more invasive than others.

What Makes a Plant Invasive?

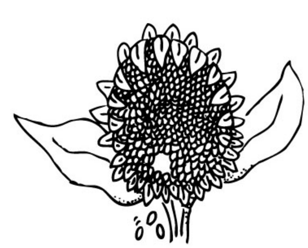
Just as the Hawaiian biota evolved in a unique ecosystem, so did the species that were brought here. Some introduced species evolved in extremely competitive environments, where they had to develop hardy characteristics to survive. When these rough and tough species reach the Hawaiian Islands, they find nothing to limit their reproduction and spread. They grow quickly and reproduce rapidly. They earn the title of "weeds." Invasive species interfere with crop production on agricultural lands and change the composition, structure, and function of native forests.

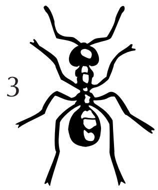
Invasive plant species outcompete other plants for light, water, and nutrients. They possess characteristics that permit them to aggressively invade new areas. A plant might be a weed if it:



Matures within one year: Plants that mature in one year or less are able to produce seeds and add to their overall numbers faster than slower-growing plants.

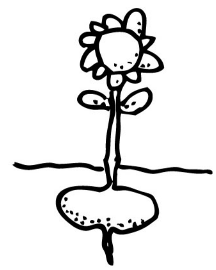
Profuse production of seeds: When plants produce large numbers of seeds, they increase their ability to take over the surrounding area and invade new areas.

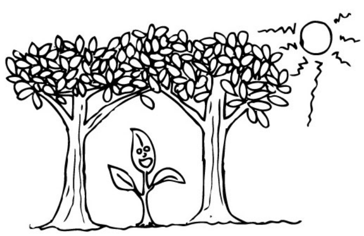




Produces spines, thorns, or burrs: These structures cause physical injury and repel animals, which will then move on to feed on native plants.

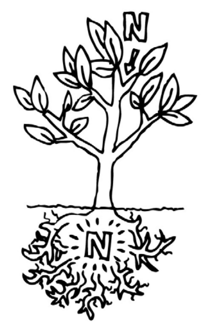
Forms underground storage organs, such as corms or tubers. Plants store energy in these structures, allowing them to resprout or grow back even after repeated cutting, browsing by animals, fires, or droughts.





Shade tolerant: Plants that tolerate low light levels are often able to invade the understory of intact, native forests and may eventually outcompete native vegetation.

Nitrogen-fixing species capture nitrogen from the atmosphere and store this natural fertilizer in their roots.



These are just a few weedy characteristics; there are many more. The Hawai‘i-Pacific Weed Risk Assessment is a series of forty-nine questions relating to a species' biology, geographic origin, and behavior. Local biologists use it to predict which plants might become invasive in the Islands. They consult published scientific records to answer yes or no questions, which results in a score for each species.

A high score means the plant poses a high risk of becoming an invasive pest in Hawai‘i and other Pacific Islands. A score of zero or below indicates that the plant is not likely to have major ecological or economic impacts, based on the screening process. Plants that score 1-6 fall in a gray area; more information is needed to determine their status.

A weed risk assessment allows consumers, nursery owners, and resource managers to make informed decisions about what nonnative plants can be safely imported and planted. By sorting out potentially problematic plants, we can preserve our unique and valuable native Hawaiian ecosystems.

Activity #2

Backyard/School Survey

Length:
Two or three class periods, allowing a week in between session two and three for specimens to dry

Prerequisite Activity:
None

Objectives:
- Develop basic botany skills: plant identification, specimen collection, and voucher preparation.
- Record field notes.

Vocabulary:

Botany/botanist
Habitat
Parallel
Palmate
Pinnate
Reproductive structures
Specimen
Terrain
Topography
Voucher

● ● ● Class Period One: *Collecting the Plant Samples*

Note:
This can be assigned as homework or done at school. Students can collect specimens from their backyards or around the schoolyard.

Materials & Setup

For each student
- Student Page: “Collecting a Scientific Specimen” pp. 83-91
- Newspaper
- Glue (Elmer’s or other brand)
- Stiff cardboard or flat wood pieces measuring 11 ½ x 16 ½ inches or larger (two per student)
- Clamps (two or more per student)
- Plant sample (collected by student)
- Field notebook (could be regular or waterproof type, such as Rite in the Rain)
- Pencil or waterproof pen
- Masking tape or paper tags
- Sealable plastic bag
- Gloves, pruning shears, trowel
- Camera (optional)
- Global positioning system (GPS) (optional)
- Acid-free paper measuring 11 ½ x 16 ½ inches or 8 ½

Instructions

1) Tell students they will be surveying their backyard or schoolyard for weedy species, collecting a plant specimen, and preparing a voucher.

2) Instruct them to review the Student Page: "Collecting a Scientific Specimen," before choosing their plant. Make sure they record the required data as they collect. Plants that are especially woody or succulent should be avoided for this exercise, as they will be difficult to press.

3) Explain that properly collected plant vouchers are essential for taxonomic identification. They provide a permanent record of information that can be reviewed or assessed as botanists learn more. A good voucher consists of a dried, pressed section of a plant containing well-preserved vegetative and reproductive structures (flowers and/or fruits). Scientific determinations are only as good as the specimens on which they are based; poor quality specimens (lacking flowers or fruits or insufficiently documented) may result in incomplete or unreliable identifications.

• • • Class Period Two: *Identifying the Plant*

Instructions

1) If possible, identify the species collected using plant guides available online and from library.

   One excellent source is: *Weeds of Hawai'i's Pastures and Natural Areas; An Identification and Management Guide* by P. Motooka et al. ©2003, College of Tropical Agriculture and Human Resources, University of Hawai'i at Manoa.

   Another source is the *Maui Early Detection Guide*.
   Download this guide at http://pbin.nbii.org/reportapest

   If you suspect any of the plants collected are invasive species, follow the instructions in the guide, or call Maui Invasive Species Committee at (808) 573-MISC.

   Main features to look for:
   Leaves. What shape are they? Are the edges smooth or toothed? Look at the leaf veins: what kind of pattern are they in? If **parallel**, the veins run side by side (like grass). If **pinnate**, small veins branch out from the middle, resembling a feather. If **palmate**, the veins have several major veins with smaller ones branching from them (like a *kukui* leaf). If the plant has needles rather than leaves, are they long or short? Covered with scales? Find identical leaves in your field guide.

   Flowers. Count whether the petals come in multiples of three, four or five. Note color, shape and arrangement of petals. Remember that "flowers" refer to the reproductive parts of the plant. Not all flowers are showy with colorful petals; grass flowers are simple tassels.

   Fruit. What type of fruits does the plant produce? Describe the fruit: shape, color, size. Is it fleshy or dry? Does it have a large pit or multiple small seeds?

2) Assist students in preparing and pressing their plant samples. See Student Page "Collecting a Scientific Specimen."

● ● ● Class Period Three: *Preparing the Voucher*

Materials & Setup

For each student

- Voucher label (print and cut Copy Master: Voucher Labels p.81)
- Glue

Instructions

Allow a week or more for pressed specimens to dry prior to this class.

1) Once the specimens have dried, have students remove them from the press and mount them on acid-free paper with glue. Encourage them to handle the brittle plants with care. Photographs of the original plant may be included on the same page. (Be sure to label photos with voucher number.)

2) Have students affix a voucher label in the lower right hand corner of their sheet with the following information:
    - Genus, species (if known; if not known write "Species unknown")
    - Family
    - Location (description and GPS coordinates, if known)
    - Habitat, topography, vegetation, soil type, altitude
    - Frequency: rare, occasional, or common (is the plant rare or plentiful in the area?)
    - Plant description: height of plant; scent; color, shape, and orientation of leaves, flowers, and fruits
    - Date of collection
    - Name of collector
    - Name of identifier
    - Voucher number (assign a unique number to each voucher to identify it according to collector and class)

3) Attach a small paper pouch to each sheet for extra flowers or fruits or any pieces of the specimen that become dislodged over time.

4) Create a voucher log, listing all of the students' voucher numbers and descriptions of each.

Journal Ideas

- How has plant identification changed with advances in genetics? Do you think field observations are as important as they were prior to this technology? Why or why not?
- If you suspect that your plant is invasive, would that change the way you collect it? What kinds of preventative measures could you employ to prevent spreading it to new areas?
- Why is collecting good data important? Imagine you are a botanist studying population changes in rare Hawaiian species. At Bishop Museum, you find a drawer full of plant vouchers. They are

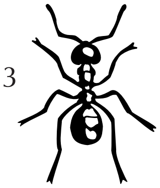
missing data concerning where they were collected or when. How might this affect your research? How might it affect conservation efforts for the species?

Assessment Tools

- Participation in schoolyard survey
- Completed voucher and voucher log
- Journal entries

Enrichment Ideas

- Have students create note cards with pressed flowers and plants.
- Team up with art teacher on botanical drawing exercises.
- Substitute marine plants or insects.



Genus, species: ____________________
Family: ____________________
Location: ____________________
Habitat: ____________________
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Frequency: rare occasional frequent
Plant description: ____________________
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Date collected: ____________________
Collector: ____________________
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Frequency: rare occasional frequent
Plant description: ____________________
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Date collected: ____________________
Collector: ____________________
Identifier: ____________________
#: ____________________

Collecting a Scientific Specimen

1) Survey your surroundings. Take some time observing the various trees, shrubs, and grasses you see. Notice the differences in leaf shapes and reproductive structures (seeds or fruits). Jot down some notes in your field notebook about the habitat. Is the soil rocky, sandy, volcanic, hard, or soft? Is the terrain steep or hilly? How many different plants can you identify?

2) Don't choose an especially woody or succulent plant for this exercise, as it will be difficult to press. Use gloves to avoid coming in contact with thorns or sap. Your sample should represent the average size, variation, and appearance of the plant. Include several leaves, flowers, fruits and/or seeds, and roots, if possible.

3) Use masking tape or a paper tag to label your specimen with a collection number that corresponds to an entry in your field notebook.

4) In your field notebook report the following information:

   - Your name
   - Date
   - Exact location. (Include address and specific reference to land features. Describe well enough for someone to return to this location. If you have a global position system [GPS] unit, include the coordinates.)
   - Habitat, topography, vegetation, soil type, altitude
   - Frequency: rare, occasional, or common
   - Plant description: height of plant; scent; color, shape, and orientation of leaves, flowers, and fruits.

5) Draw and/or photograph the plant as it appears in nature, focusing on the above-mentioned characteristics.

6) Tips for pressing:
   - Press plants as soon as possible after collection. If you need to keep them overnight before pressing, seal them individually in plastic bags with plenty of air and a paper towel to absorb moisture, and place in the refrigerator.
   - Before pressing, shake or wash roots to remove any mud or sand. Be sure to dry thoroughly before pressing, otherwise specimen will rot.
   - Arrange the specimen carefully on acid-free paper. Placement is important; once dry, plant parts cannot be arranged without incurring damage. If necessary, fold the stem to insure a portion of the base is intact and no plant parts project beyond the newspaper.
   - Both top and bottom surfaces of the leaves and reproductive structures should be visible, so at least one leaf and one flower should be turned over.
   - Some flowers should be pressed open, some closed. If possible, one flower should be dissected to show internal structures.

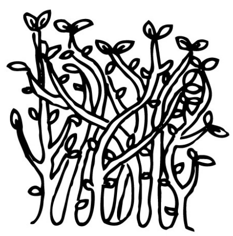
- Large fruits or bulbs are cut in half lengthwise or in slices prior to pressing. Succulent materials such as cactus stems may need to be sliced open and some of the fleshy interior scraped out.

7) Place newspapers above and below specimen to absorb moisture and prevent rot. Place specimen and newspapers between two pieces of wood or stiff cardboard and secure with clamps. If necessary, replace moist newspapers after first or second day. Otherwise, do not disturb the press until the plant material is completely dry. (A week should be sufficient for most plants.)

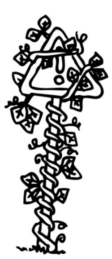
Weedy Checklist

Your assignment is to collect a weedy species from your schoolyard or backyard. You probably already know how to spot a weed. Biologists use the following characteristics to identify pest plants. A plant may have one or two of these qualities and not be a pest. If it has several of these characteristics, it's probably a weed.

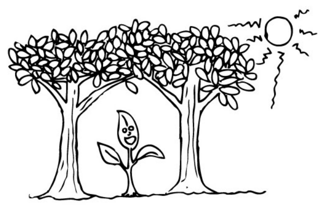
How does it grow?



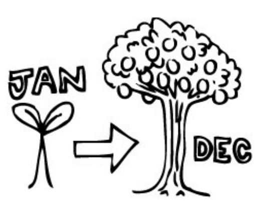
Is there a lot of it growing in one area? Plants that grow in dense thickets deprive other vegetation of light, water, and nutrients. They can prevent other plants from growing in an area. Such thick growth also impedes the movement of humans and animals in an area.



Is it climbing on or smothering other plants? Vines and climbing plants can completely shroud other vegetation, including trees, blocking out sunlight and eventually weakening or killing the underlying plants.



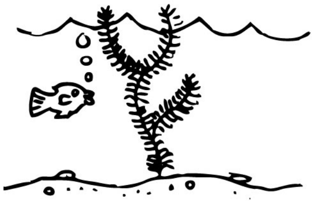
Is it shade tolerant? Plants that tolerate low light levels are often able to invade the understory of intact, native forests and may eventually outcompete native vegetation.



Does grow quickly? Plants that mature in one year or less are able to produce seeds rapidly. They tend to invade new areas and persist in areas much longer than slower growing plants.

What kind of plant is it?

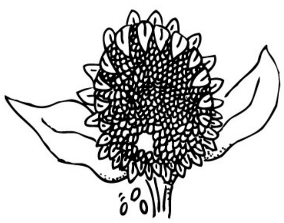
Is it a grass? Grasses tend to be very competitive. They are adapted to grow quickly, disperse rapidly, and form thick cover. They may also tolerate grazing or fires that can kill other plants.



Is it aquatic? Aquatic plants introduced into new areas almost always become highly invasive. When freed from natural competitors or predators, they often experiencing explosive growth rates and quickly dominate their new habitat.

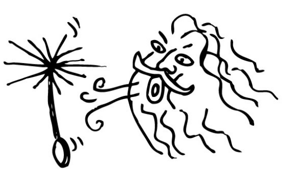
Is it a melastome? Many plants in the melastome family have proven themselves to be fast-spreading pests throughout the Pacific. Miconia, one of the worst weeds in Hawaiʻi, is a melastome. You can identify members of the melastome family by their quilted leaves.

What kind of seeds does it have?



Does it produce lots of seeds? When plants produce large numbers of seeds, they increase their ability to take over an area as well as to spread away from the site and invade new areas.

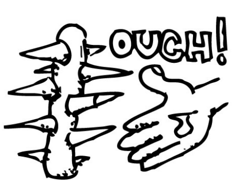
Do its seeds float? Plants with buoyant seeds or plant parts can spread rapidly and invade waterways, rivers, streams, and coastlines.



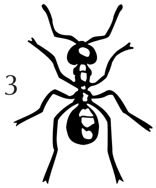
Do its seeds have propellers, wings, or other structures that easily fly away? Wind-dispersed seeds tend to be small and often have hairs, wings, or other structures that allow them to travel long distances on wind currents. These plants have the ability to invade very remote and isolated areas.

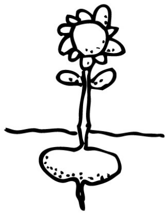
Does it have fleshy fruit? Birds like to eat fleshy or pulpy fruits that contain seeds. Birds swallow the seeds, then deposit them later, after they've flown somewhere new. Bird-dispersed plants have the ability to spread rapidly far from the original seed source.

Does it have other features?

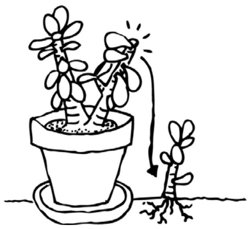


Does it have spines, thorns or burrs? Plants armed with these natural defenses can harm or injure humans and animals, and may outcompete plants lacking this protection. Spines, thorns and burrs also make removal or control of the species more difficult, and hazardous.



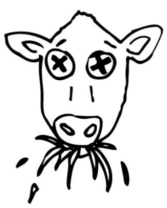


Does it have underground storage organs, such as corms or tubers? Plants store energy in these structures, allowing them to resprout or grow back even after repeated cutting, browsing by animals, fires, or droughts.



Can you break off a piece of it and successfully plant it? Some plants are able to re-sprout from pieces of stems, roots, and even leaves that either break off or are cut off from the parent plant. This enables them to spread without producing seeds, and makes control or removal of these plants difficult.

Is it an allergen, or toxic to humans? Some plants have chemicals or pollen that can cause rashes, severe allergic reactions, sickness, or even death to people that come into contact with or consume them.



Is it toxic to animals? Poisonous plants can harm the health of pets and livestock that accidentally eat or come into contact with them. They can thrive even in areas with pressure from grazing animals.

Is it a fire hazard? Certain plants (especially some grasses) increase the risk of fire to both natural and residential areas. They may produce a lot of biomass that easily burns when it dries out, or they may contain highly flammable chemicals in their leaves or sap.

Activity #3

Ecosystem Engineers I: Strawberry Guava

Length:
Two class periods with two-week lab in between

Prerequisite Activity:
None

Objectives:
- Identify how an invasive plant species might alter soil or other habitat conditions to affect the surrounding ecosystem.
- Explore how invasive plants can affect native seedling germination and growth.
- Formulate a hypothesis and design and conduct a lab to observe effects caused by invasive species.
- Create a poster presentation of lab results.

Vocabulary:

bioactive
control
ecosystem engineer
endemic
germination
hypothesis
invasive
mean number
median
scientific method
variable

● ● ● Class Period One: *Designing Labs*

In Advance

Acquire 30-60 Petri dishes, 1 package of lettuce seeds, 1 head of lettuce (same species as seeds), and enough strawberry guava leaves to fill a regular sized grocery bag. (You can find strawberry guava trees in Iao Valley, or along Hana Highway.) Set aside a place in your classroom for the dishes. It should be easily accessible and under a light table or window.

Materials & Setup

For Group Discussion and Lab Activity
- Scientific method chart
- Blender
- Water
- 3 spray bottles
- Petri dishes (3 per group)
- Paper towels cut into circles the size of Petri dish
- Lettuce seeds (30 seeds per group)
- Lettuce

- Strawberry guava leaves
- Labels for Petri dishes and indelible markers
- Rulers
- Teacher Background “Scientific Method Chart” p 97 and Copy Master “Station Instructions” p 99 (You may want to display the latter with a projector
- Student Page “Ecosystem Engineers” p 101-103

For each group of students
- Student Pages “Ecosystem Engineers Lab Report” p 105 and“Daily Data Sheet” p 107-111

Instructions

NOTE: you can prepare the lab stations yourself or assign a few students to set up and “man” each station.

1. Blend two handfuls of lettuce leaves with 1-3 cups of water until little or no plant material is visible. Pour into spray bottle. Repeat with strawberry guava leaves. Fill one spray bottle with plain water. Label spray bottles.

   Cut paper towels into circles that fit inside the Petri dishes. Print out Copy Master “Station Instructions.” Cut into sections and place each instruction at its appropriate station.

2. Set up five stations for students to visit in order.
   Station #1: Petri dishes, paper towel circles, labels, and indelible markers
   Station #2: Lettuce seeds (10 seeds per dish)
   Station #3: 3 spray bottles - one filled with water, one with strawberry guava mixture, and one with lettuce mixture
   Station #4: Student Page “Ecosystem Engineers”
   Station #5: Student Pages “Ecosystem Engineers Lab Report” and “Daily Data Sheet” (one each per group)

3. Lead a discussion on the scientific method, using Teacher Background “Scientific Method Chart.”

   Question: What are the steps of the scientific method?
   Answer: The scientific method begins when you 1) ask a general question and 2) conduct some background research. Next, you 3) develop a hypothesis and 4) test the hypothesis in a controlled experiment. 5) Collect and analyze results. 6) Determine whether your hypothesis is true or false, based on your results. 7) Report your results and conclusion. If your hypothesis is false, you can begin the process again with a different hypothesis.

   Writing a hypothesis as an “if... then” statement is a prediction of the results you need to support the hypothesis.

   For example:
   If strawberry guava compounds stifle plant growth, then seeds receiving the compounds should grow 20 percent shorter than the control.

4. Tell students that they will be replicating the 2010 experiment of a University of Hawai‘i student, Kelly Bongolan. Explain that scientists repeat one other's experiments in order to verify results. When the same results can be demonstrated time after time, a hypothesis moves from a guess to an accepted scientific fact.

5. Break the students into groups of 2-3 and have them visit each station.

6. Arrange Petri dishes under a window or light table. Each group will spray their Petri dishes every day for two weeks, using the appropriate spray bottle for each dish. (Assign students to take their groups' dishes home over weekends.) They will record data for each Petri dish (control, lettuce and strawberry guava) on their Student Page "Daily Data Sheet." After the seedlings sprout, students will record the total number of sprouted seedlings, the root length of the two largest seedlings in each dish and the shoot length of the two largest seedlings in each dish.

   Dishes need to remain moist. Depending on the classroom climate, they may need to be sprayed more than once a day. Also, consider refrigerating your spray mixtures, or mix fresh batches every few days.

● ● ● Class Period Two: *Analyzing and Reporting on Results*

Materials & Set Up

For each student:

- Student page "Lab Report Guidelines" p. 113
- Graph paper or access to computer

Instructions

1) After two weeks, collect the completed Student Page "Daily Data Sheet" from each group. Summarize the entire class's data in charts and graphs. These charts and graphs can be drawn on graph paper or created as computer spreadsheets. Discuss why scientists calculate their results in a variety of ways, ie: using mean number and median.

   For example, have students calculate the mean number of days it took seeds to germinate for the control and each of the variables. Determine the median days to germination and display in a table. Do the same for seedling growth. (You can compare the class's results to those collected by University of Hawai‘i student Kelly Bongolan. Her poster is included in the Teacher Background.)

2) Hand out the "Lab Report Guidelines" worksheet and review it with the students. Have students complete their "Ecosystem Engineers Lab Report" based on the data gathered by the entire class.

3) The students will then make a poster out of their experiment to put on display for the class. The poster should include their hypothesis, a brief version of the procedure, and the results, including the graphs they made.

4) Place the posters on display in the classroom. Students can do a gallery walk, providing construc-

tive and positive comments about each poster by writing it on a sticky note and placing it on the poster.

5) Have students turn in their “Ecosystem Engineers Lab Report.”

Journal Ideas

- How do invasive species alter habitats and ecosystems? Name five ways.
- Imagine a forest that contains many different species, such as trees, shrubs, mosses, ferns, and vines. Maybe you have visited one recently. How does it feel? What does it look and sound like? How does it smell? What kind of birds and insects live there? Now imagine a forest with just one or two species, such as a mountainside dominated by ironwood or strawberry guava trees. How does it feel? How is it different from the diverse forest described above? Do you think the same birds and insects live in both? Why or why not?

Assessment Tools

- Daily data sheets
- Lab reports
- Posters
- Journal entries

Further Enrichment

- Partner with Maui Digital Bus to conduct related experiments in the field and lab. The program’s educators can tailor lessons to meet the teacher’s goals and can provide high-tech equipment via their mobile laboratory. Teachers who work with the Digital Bus gain access to their lending library, which includes digital microscopes, GPS/GIS, temperature sensors, motion detectors, and water quality kits. www.digitalbus.org

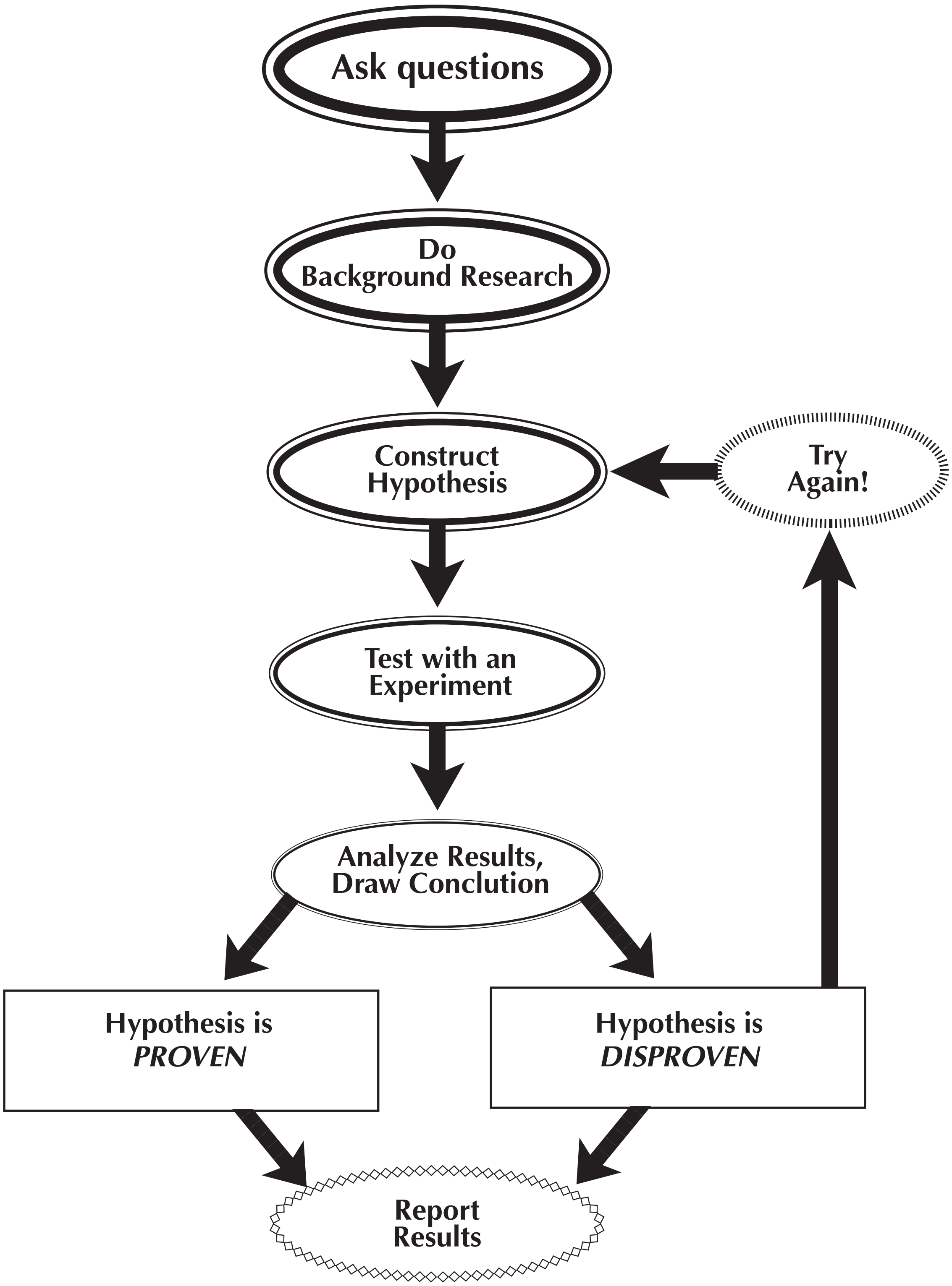
- Take a field trip to Hosmer’s Grove. Contact East Maui Watershed Partnership or Haleakalā National Park staff for a guided tour of the Bird Loop. Observe and discuss with students why the forest’s older *‘ōhi‘a* trees are dying while the surrounding pine trees around are thriving. Introduce the concept of “ecosystem engineers,” invasive species that directly change a habitat or ecosystem.

East Maui Watershed Partnership
(808) 573-6999
coordinator@eastmauiwatershed.org
www.eastmauiwatershed.org

Haleakalā National Park
(808) 572-4453
www.nps.gov/hale/forteachers

Teacher Background

Scientific Method Chart



Station Instructions

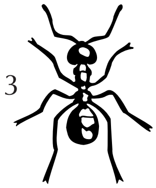
Station #1
Select three Petri dishes for your team. Fill each dish with a paper towel circle. Label one "strawberry guava," another "lettuce" and the last "control." Make sure your team name is on each dish.

Station #2
Place ten lettuce seeds in each dish.

Station #3
Spray 20-40 squirts of each mixture into the appropriate dish.

Station #4
Read "Ecosystem Engineers."

Station #5
Fill out questions 1-3 of your team's "Ecosystem Engineers Lab Report." Frame your hypothesis as an "If…Then" statement. Be specific. Example: If strawberry guava chemical compounds stifle seedling growth, the seedlings exposed to strawberry guava will show 20 percent less growth than the control.



Ecosystem Engineers

Exotic species can affect the environments they invade in many ways. Some have the ability to create, modify, or destroy habitats. Aggressive alien plants can monopolize sunlight or territory. They can alter the temperature or acidity of the soil, and the availability of nutrients. In doing so, they can change wetlands to forests or forests to grasslands. They can reduce diverse ecosystems into single-species fields.

Large miconia tree in Hāna rain forest, discovered and controlled by Maui Invasive Species field crew. (Photo courtesy of MISC)

Biologists call this "ecosystem engineering."

Miconia, a large-leafed tree from Central and South America, is an example of an ecosystem engineer. As it invades Hawaiian rain forests, it unfurls giant, umbrella-like leaves. These huge leaves block out the sun for plants trying to grow below. While miconia seedlings thrive in deep shade, most native Hawaiian rain forest plants need some sunshine. They are adapted to the filtered light that falls through a canopy of *koa* and *'ōhi'a* trees.

After miconia pulls the shade down on the forest, it fills the soil with its seeds. Each mature miconia plant produces millions of tiny seeds. These seeds germinate into a carpet of young miconia plants, leaving no room for any other plants to grow. Before long, what was a sunlit rain forest brimming with diverse species of shrubs, vines, ferns, and trees, is now a dark field populated by a single tree species: miconia.

Some plants drop smothering blankets of leaves or needles on the ground. What do you see under a pine tree or an ironwood tree? How might that affect how other plants are able grow?

Chemical Warfare

Some plants alter the chemical composition of the soil where they grow. Conifers increase acidity in the soil. Since many plants don't do well in acidic environments, this limits what can grow alongside a conifer.

Other plants release poisons—chemicals that stifle the growth of neighboring plants. These plant toxins can affect neighboring plants in different ways. They may inhibit other plants' root growth, or prevent other plants from getting nutrients. Toxins can be present in any part of the plant: leaves, flowers, roots, fruits, or stems. They are also found in the surrounding soil after plant parts have decomposed. Examples of plants that produce toxins include sunflowers, sweet potato, alfalfa, black walnut, pine, ironwood, and eucalyptus.

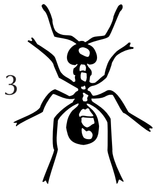
Strawberry guava might also fall onto this list. Originally from Southeastern Brazil's coastal plains, strawberry guava was brought to the Hawaiian Islands in 1825 and has since become seriously invasive.

Though many people enjoy its fruit and wood, strawberry guava is one of the greatest threats facing native Hawaiian forests. It is now found on six of the eight main islands, where it successfully invades native *koa* and *'ōhi'a* forests. It grows rapidly and aggressively, efficiently spreads its seeds, and survives in areas with minimal sunlight. If that weren't enough of an advantage, strawberry guava may have a secret weapon: toxic leaf material.

Strawberry guava seedlings emerging from under the leaf litter of parent trees. (Photo courtesy of Forest and Kim Starr)

Strawberry guava seedlings do well under a canopy of strawberry guava trees—but few other species can survive in this environment. Why? It could be because the shade is too dark and doesn't afford seedlings of other species enough light. Or perhaps the leaf litter is too heavy, and other species' seedlings can't push through it. Or maybe the explanation has to do with chemicals in the leaf litter. In 2010, a University of Hawai'i student created a lab experiment to investigate whether strawberry guava leaves might contain toxins that suppress the growth of other plants.

You will be conducting your own lab experiments to see firsthand how invasive plants engineer their environments.



Ecosystem Engineers Lab Report

Group Name: ______________________________ *Date:* ______________

1. Hypothesis (State in "If….Then" format): ______________________________

2. Procedure (Control, Variable, Materials, Steps): ______________________________

3. Methods of Data Analysis: ______________________________

4. Results ______________________________

5. Conclusion ______________________________

Daily Data Sheet - Control

Group Name: ____________________

Date	Water Amount	Number of Seedlings	Root Length #1	Root Length #2	Shoot Length #1	Shoot Length #1	Notes

Daily Data Sheet - Lettuce

Group Name: ______________________

Date	Water Amount	Number of Seedlings	Root Length #1	Root Length #2	Shoot Length #1	Shoot Length #1	Notes

Daily Data Sheet - Strawberry Guava

Group Name: ______________________

Date	Water Amount	Number of Seedlings	Root Length #1	Root Length #2	Shoot Length #1	Shoot Length #1	Notes

Lab Report Guidelines

Lab reports include the following elements:

Introduction:
Background information justifying why you are testing your specific hypothesis. The introduction should end with a clear statement of your hypothesis and expectations.

Methods:
Detailed description of how your experiment was conducted. It should be detailed enough that someone else could read it and recreate your experiment.

Results and Data Analysis:
Clearly describe your results and what you did to make sense of the data. This includes talking about how and why you made each graph or table.

Conclusions:
Interpret your results and make some conclusions about your research. If no clear conclusions can be made, talk about how you could improve the experiment. Include discussion of future experiments that could be done based on the knowledge that you obtained through your experiment.

Activity #4

Ecosystem Engineers II: Ironwood

Length:
Two class periods with two-six weeks lab in between

Prerequisite Activity:
None.

Objectives:
- Identify how an invasive plant species might alter soil or other habitat conditions to affect the surrounding ecosystem.
- Explore how invasive plants can affect native seedling germination and growth.
- Formulate a hypothesis and design and conduct a lab to observe effects caused by invasive species.
- Create a poster presentation of lab results.

Vocabulary:

bioactive
control
ecosystem engineer
endemic
germination
hypothesis
invasive
mean number
median
scientific method
variable

● ● ● Class Period One: *Designing Labs*

In Advance

Acquire 30-60 2” pots (depending on class size), potting soil, enough ironwood needles to fill a regular sized grocery bag and 120-150 *‘a‘ali‘i* seeds. Set aside a place in your classroom for the pots. It should be easily accessible under a light table or window.

Source for *‘a‘ali‘i* seeds and growing information: Ho‘olawa Farms, 3 Kahiapo Pl., Ha‘ikū, HI 96708. (808) 575-5099 www.hoolawafarms.com

Collect ironwood needles at Spreckelsville at the beach, along Waihe‘e Beach Road, or Office Road in Kapalua.

Tip for the Lab

Germinating ‘a‘ali‘i seeds. Round, black *‘a‘ali‘i s*eeds are found within papery capsules. Remove the seeds from the capsules and soak them for twenty-four hours in water that was initially boiling hot. Plant them in clean pots of well-drained potting mix. Water daily. The seeds should sprout between two weeks and one month.

Materials & Setup

For Group Discussion and Lab Activity

- Water
- Potting soil
- Spray bottle
- 2” pots (2 per group)
- *‘A‘ali‘i* seeds (10 seeds per group)
- Labels and indelible markers
- Ironwood needles
- Rulers
- Teacher Background Page “Station Instructions” pp. 121-123 and Copy Master“Scientific Method Chart” pp. 119 (You may want to display the latter with a projector)
- Student Page “Ecosystem Engineers” pp. 125-127

For each group of students

- Student Pages “Ecosystem Engineers Lab Report” pp. 129 and “Daily Data Sheet” pp. 131

Instructions

NOTE: you can prepare the lab stations yourself or assign a few students to set up and “man” each station.

1. Print out Teacher Background “Station Instructions.” Cut into sections and place each instruction at its appropriate station.

   Set up six stations for students to visit in order:
   - Station #1: Potting soil and 2” pots (2 per group, filled ¾ way with soil)
   - Station #2: ‘A‘ali‘i seeds (5 seeds per pot)
   - Station #3: Labels and indelible markers
   - Station #4: ironwood needles (enough to cover pots with 1” layer), spray bottle filled with water
   - Station #5: Student Page “Ecosystem Engineers”
   - Station #6: Student Pages “Ecosystem Engineers Lab Report” and “Daily Data Sheets”

2. Lead a discussion on the scientific method.

   Question: What are the steps of the scientific method?
   Answer: The scientific method begins when you 1) ask a general question and 2) conduct some background research. Next, you 3) develop a hypothesis and 4) test the hypothesis in a controlled experiment. 5) Collect and analyze results. 6) Determine whether your hypothesis is true or false, based on your results. 7) Report your results and conclusion. If your hypothesis is false, you can begin the process again with a different hypothesis.

   Writing a hypothesis as an “if... then” statement is a prediction of the results you need to support the hypothesis. For example:

If ironwood needle cover benefits seedling growth, the seedlings germinating under ironwood needles will grow 20 percent taller than the control.

3. Break the students into groups of 2-3 and have them visit stations.

4. Arrange pots under a window or light table. Each group will spray water their pots every day for 2-6 weeks. (Assign students to take their groups' pots home over weekends.) They will record data for each pot (control and ironwood cover) on their Student Page "Daily Data Sheet." After the seedlings sprout, students will record the total number of sprouted seedlings and the height of the two largest seedlings from each pot.

● ● ● **Class Period One:** *Analyzing and Reporting on Results*

Materials & Set Up

For Each Student:

- Student page "Lab Report Guidelines" p. 133
- Graph paper or access to computer

Instructions

1) After two weeks, collect the completed Student Page "Daily Data Sheets" from each group. Summarize the entire class's data in charts and graphs. These charts and graphs can be drawn on graph paper or created as computer spreadsheets. Discuss why scientists calculate their results in a variety of ways, ie: using mean number and median.

   For example, have students calculate the mean number of days it took seeds to germinate for both the variable and the control. Display germination time in a bar graph, with the x-axis having two categories (ironwood cover, no ironwood cover) and the y-axis being the average number of days. Do the same for seedling growth.

   Determine the median days to germination and display in a table. Do the same for seedling growth.

2) Hand out the "Lab Report Guidelines" worksheet and review it with the students. Have students complete their "Ecosystem Engineers Lab Report" based on the data gathered by the entire class.

3) The students will then make a poster out of their experiment to put on display for the class. The poster should include their hypothesis, a brief version of their procedure, and their results, including the graphs they made.

4) Place the posters on display in the classroom. Students can do a gallery walk, providing constructive and positive comments about each poster by writing it on a sticky note and placing it on the poster.

5) Have the students turn in their "Ecosystem Engineers Lab Report."

Journal Ideas

- How do invasive species alter habitats and ecosystems? Name five ways.
- Imagine a forest that contains many different species, such as trees, shrubs, mosses, ferns, and vines. Maybe you have visited one recently. How does it feel? What does it look and sound like? How does it smell? What kind of birds and insects live there? Now imagine a forest with just one or two species, such as a mountainside dominated by ironwood or strawberry guava trees. How does it feel? How is it different from the diverse forest described above? Do you think the same birds and insects live in both? Why or why not?

Assessment Tools

- Daily data sheets
- Lab reports
- Posters
- Journal entries

Further Enrichment

- Partner with Maui Digital Bus to conduct related experiments in the field and lab. The program's educators can tailor lessons to meet the teacher's goals and can provide high-tech equipment via their mobile laboratory. Teachers who work with the Digital Bus gain access to their lending library, which includes digital microscopes, GPS/GIS, temperature sensors, motion detectors, and water quality kits. www.digitalbus.org

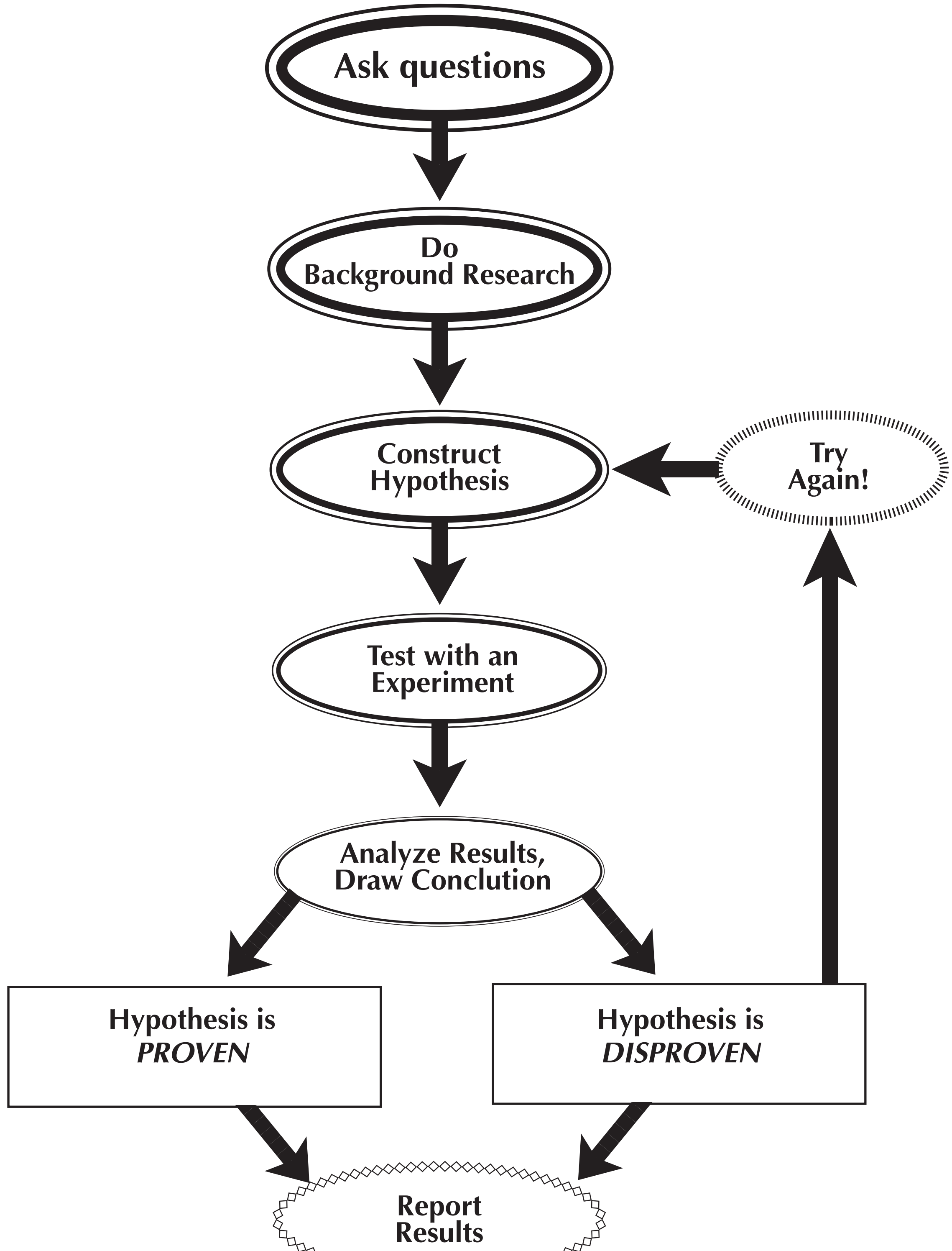
- Take a field trip to Hosmer's Grove. Contact East Maui Watershed Partnership or Haleakalā National Park staff for a guided tour of the Bird Loop. Observe and discuss with students why the forest's older *ʻōhiʻa* trees are dying while the surrounding pine trees around are thriving. Introduce the concept of "ecosystem engineers," invasive species that directly change a habitat or ecosystem.

East Maui Watershed Partnership
(808) 573-6999
coordinator@eastmauiwatershed.org
www.eastmauiwatershed.org

Haleakalā National Park
(808) 572-4453
www.nps.gov/hale/forteachers

Teacher Background

Scientific Method Chart



Station Instructions

Station #1
Select two pots for your team. Fill each pot ¾ full with potting soil.

Station #2
Plant five ʻaʻaliʻi *seeds in each pot. The rule of thumb is the smaller the seed, the shallower their spot in the soil.* ʻAʻaliʻi *seeds are tiny. Gently press them into the soil no more than one half inch.*

Station #3
Label your pots with your team name.

Station #4
Cover one pot with 1-inch layer of ironwood needles and spray both with 20-40 squirts of water (or until soil is damp).

Station #5
Read "Ecosystem Engineers."

Station #5
Fill out questions 1-3 of your team's "Ecosystem Engineers Lab Report." Frame your hypothesis as an "If…then" statement. Be specific. Example: if ironwood needle cover benefits seedling growth, the seedlings grown under ironwood needles will grow 20 percent taller than the control.

Ecosystem Engineers

Exotic species can affect the environments they invade in many ways. Some have the ability to create, modify, or destroy habitats. Aggressive alien plants can monopolize sunlight or territory. They can alter the temperature or acidity of the soil, and the availability of nutrients. In doing so, they can change wetlands to forests or forests to grasslands. They can reduce diverse ecosystems into single-species fields.

Biologists call this "ecosystem engineering."

Large miconia tree in Hāna rain forest, discovered and controlled by Maui Invasive Species field crew. (Photo courtesy of MISC)

Miconia, a large-leafed tree from Central and South America, is an example of an ecosystem engineer. As it invades Hawaiian rain forests, it unfurls giant, umbrella-like leaves. These huge leaves block out the sun for plants trying to grow below. While miconia seedlings thrive in deep shade, most native Hawaiian rain forest plants need some sunshine. They are adapted to the filtered light that falls through a canopy of *koa* and *ʻōhiʻa* trees.

After miconia pulls the shade down on the forest, it fills the soil with its seeds. Each mature miconia plant produces millions of tiny seeds. These seeds germinate into a carpet of young miconia plants, leaving no room for any other plants to grow. Before long, what was a sunlit rain forest brimming with diverse species of shrubs, vines, ferns, and trees, is now a dark field populated by a single tree species: miconia.

Some plants drop smothering blankets of leaves or needles on the ground. What do you see under a pine tree or an ironwood tree? How might that affect how other plants are able grow?

Chemical Warfare

Some plants alter the chemical composition of the soil where they grow. Conifers increase acidity in the soil. Since many plants don't do well in acidic environments, this limits what can grow alongside a conifer.

Other plants release poisons—chemicals that stifle the growth of neighboring plants. These plant toxins can affect neighboring plants in different ways. They may inhibit other plants' root growth, or prevent other plants from getting nutrients. Toxins can be present in any part of the plant: leaves, flowers, roots, fruits, or stems. They are also found in the surrounding soil after plant parts have decomposed. Examples of plants that produce toxins include sunflowers, sweet potato, alfalfa, black walnut, pine, ironwood, and eucalyptus.

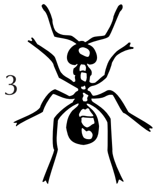
Strawberry guava might also fall onto this list. Originally from Southeastern Brazil's coastal plains, strawberry guava was brought to the Hawaiian Islands in 1825 and has since become seriously invasive.

Though many people enjoy its fruit and wood, strawberry guava is one of the greatest threats facing native Hawaiian forests. It is now found on six of the eight main islands, where it successfully invades native *koa* and *ʻōhiʻa* forests. It grows rapidly and aggressively, efficiently spreads its seeds, and survives in areas with minimal sunlight. If that weren't enough of an advantage, strawberry guava may have a secret weapon: toxic leaf material.

Strawberry guava seedlings emerging from under the leaf litter of parent trees. (Photo courtesy of Forest and Kim Starr)

Strawberry guava seedlings do well under a canopy of strawberry guava trees—but few other species can survive in this environment. Why? It could be because the shade is too dark and doesn't afford seedlings of other species enough light. Or perhaps the leaf litter is too heavy, and other species' seedlings can't push through it. Or maybe the explanation has to do with chemicals in the leaf litter. In 2010, a University of Hawaiʻi student created a lab experiment to investigate whether strawberry guava leaves might contain toxins that suppress the growth of other plants.

You will be conducting your own lab experiments to see firsthand how invasive plants engineer their environments.



Ecosystem Engineers Lab Report

Group Name: ______________________________ *Date:* ______________

1. Hypothesis (State in "If….Then" format): ______________________________

2. Procedure (Control, Variable, Materials, Steps): ______________________________

3. Methods of Data Analysis: ______________________________

4. Results ______________________________

5. Conclusion ______________________________

Daily Data Sheet

Team Name: ______________________________

Date	Water Amount	Number of Seedlings	Height #1	Height #2	Notes
CONTROL					
IRONWOOD					

Lab Report Guidelines

Lab reports include the following elements:

Introduction:
Background information justifying why you are testing your specific hypothesis. The introduction should end with a clear statement of your hypothesis and expectations.

Methods:
Detailed description of how your experiment was conducted. It should be detailed enough that someone else could read it and recreate your experiment.

Results and Data Analysis:
Clearly describe your results and what you did to make sense of the data. This includes talking about how and why you made each graph or table.

Conclusions:
Interpret your results and make some conclusions about your research. If no clear conclusions can be made, talk about how you could improve the experiment. Include discussion of future experiments that could be done based on the knowledge that you obtained through your experiment.

Activity #5

Ecosystem Engineers III: Nitrogen Fixers

Length:
Two class periods with 5-6 week lab in between

Prerequisite Activity:
None.

Objectives:
- Identify how an invasive plant species might alter soil or other habitat conditions to affect the surrounding ecosystem.
- Explore how bacteria help certain plants harness airborne nitrogen.
- Formulate a hypothesis and design and conduct a lab to observe nitrogen accumulation in root nodes.
- Create a poster presentation of lab results.

Vocabulary:

Bacteria
Biomass
Inoculate
Nitrogen-fixing
Nodules
Symbiotic

• • • Class Period One: *Designing Labs, Nitrogen Fixers*

In Advance

Order lab equipment: Rapitest Soil Test Kit and clover seeds inoculated with *Rhizobium leguminosarum* (1 packet), both available from Carolina Biological Supply Company at www.carolina.com

Materials & Setup

Group Discussion Series
- 27 small pots
- Potting soil without fertilizer *
- 1 packet clover seeds
- 1 packet clover seeds inoculated with *Rhizobium leguminosarum***
- Rapitest Soil Test Kit**
- Nitrogen fertilizer
- Ruler
- Metric scale
- Teacher Background “Scientific Method Chart” p. 139 (You may want to display this with a projector)

* Potting soil without fertilizer is ideal, but may be hard to find. If you are unable to find potting soil without fertilizer, establish with the class that all three test pots (no nitrogen added, nitrogen-fixing bacteria added, and nitrogen fertilizer added) will be starting with a baseline of nitrogen.

**Available from Carolina Biological Supply Company at www.carolina.com

Note: Adult supervision required during use of nitrogen fertilizer.

For each student:

- Student Pages: "Nitrogen-Fixers: Friends or Foes?" p. 141 "Daily Data Sheet" p. 147 "Lab Report" p. 143, and "Lab Report Guidelines" p. 145.

Instructions

1) Read the Student Page "Nitrogen-Fixers: Friends or Foes?" aloud in class.

2) Lead a discussion on the scientific method using Teacher Background "Scientific Method Chart." Project or draw diagram on board.

   Question: What are the steps of the scientific method?
   Answer: The scientific method begins when you 1) ask a general question and 2) conduct some background research. Next, you 3) develop a hypothesis and 4) test the hypothesis in a controlled experiment. 5) Collect and analyze results. 6) Determine whether your hypothesis is true or false, based on your results. 7) Report your results and conclusion. If your hypothesis is false, you can begin the process again with a different hypothesis.

3) Pass out the Student Pages "Ecosystem Engineers Lab Report" and "Lab Report Guidelines."

4) Tell students to develop a hypothesis to test (for example: seeds inoculated with *Rhizobium leguminosarum* will have 25 percent larger biomass after six weeks than non-inoculated seeds). Have them write out their hypothesis, materials, procedure (including what they intend to measure), and how they will compare their data to their control on their worksheet. Students can compete for whose hypothesis is the most accurate.

5) Have each student keep their own notes for their experiment because they will be putting together a poster at the end of their experiment. This experiment will be ongoing, with students watering/monitoring their seeds every other day for 5-6 weeks.

6) Make sure pots have holes in the bottom to allow the roots to "breathe." Measure equal amounts of soil into each of the pots. Moisten the soil in each pot with the equal amounts of water.

7) Choose students to label nine pots "no nitrogen added," nine pots "nitrogen fertilizer," and nine pots "nitrogen-fixing bacteria." Number the pots 1-9 in each set. In the pots labeled "no nitrogen added" and "nitrogen fertilizer," plant 10 seeds from the regular clover packet. In the pots labeled "nitrogen-fixing bacteria" plant ten *Rhizobium leguminosarum*-inoculated clover seeds. Plant seeds according to seed packet instructions.

8) Set the pots near a window where they can access natural light, or beneath a timed light source that simulates natural light. Set a schedule for watering and recording data. Each student should take a turn or several turns.

9) Explain to students that when it is their turn to water, they are responsible for doing an effective job and recording data that the entire class will be using.

   Pots labeled "No nitrogen added" and "*Rhizobium leguminosarum*" get regular water. Pots labeled "nitrogen fertilizer" get water and nitrogen fertilizer at the brand of fertilizer's recommended concentration. (Note that they may not need to add fertilizer at each watering.) Soil should be kept moist. Depending on your classroom environment, you may have to water more or less frequently.

   At each watering, have students measure the amount of nitrogen in the soil of each pot (use the Rapitest Soil Test Kit), number of seedlings per pot, and the height of two tallest seedlings per pot as they grow. They will record their data on three separate "Daily Data Sheets." Tell them to list any changes they notice in the plants' health in the "notes" section.

10) Clover will grow to maturity in 5–6 weeks. When clover plants are mature, proceed with experiment.

11) After the plants have matured, instruct students to carefully remove each plant from the soil and shake off any excess soil from the roots. Have them measure the total biomass of each plant on the scale and record data on worksheet.

12) As a class, compare the average nitrogen levels in each type of soil and the average biomass of the clover grown in each type of soil. Which type of soil had the highest levels of nitrogen? Which type of soil produced the greatest biomass of clover? Was there any noticeable difference in the health or appearance of the clover grown in the different soils?

● ● ● **Class Period One:** *Analyzing and Reporting on Results*

Materials & Set Up

For each student:

- Graph paper or access to computer

Instructions

1) After 5-6 weeks, collect the completed Student Page "Daily Data Sheets" from each group. Summarize the entire class's data in charts and graphs. These charts and graphs can be drawn on graph paper or created as computer spreadsheets. Discuss why scientists calculate their results in a variety of ways, ie: using mean number and median.

   For example, have students calculate the mean number of days it took seeds to germinate for both the variable and the control. Display germination time in a bar graph, with the x-axis having two categories (nitrogen added, no nitrogen) and the y-axis being the average number of days. Do the same for seedling growth.

Determine the median days to germination and display in a table. Do the same for seedling growth.

Graph change in nitrogen levels (if any) over time.

2) Review the "Lab Report Guidelines" with the students. Have students complete their "Ecosystem Engineers Lab Report" based on the data gathered by the entire class.

3) The students will then make a poster to put on display for the class. The poster should include their hypothesis, a brief version of their procedure, and their results, including the graphs they made.

4) Place the posters on display in the classroom. Students whose hypotheses most closely matched the actual results can give a short 2-3 minute presentation on their research posters. Afterwards, the class can do a gallery walk, providing constructive and positive comments about each poster by writing it on a sticky note and placing it on the poster.

5) Have the students turn in their "Ecosystem Engineers Lab Report."

Journal Ideas

- How do invasive species alter habitats and ecosystems? Name five ways.
- When people shop for landscaping plants, most look for exotic species that are hardy and fast growing. How might this be a problem for the native environment beyond the landscaped yard?
- Many native Hawaiian plants grow slowly and are conservative in their use of resources. Why might that be? How could these characteristics help a plant survive?

Assessment Tools

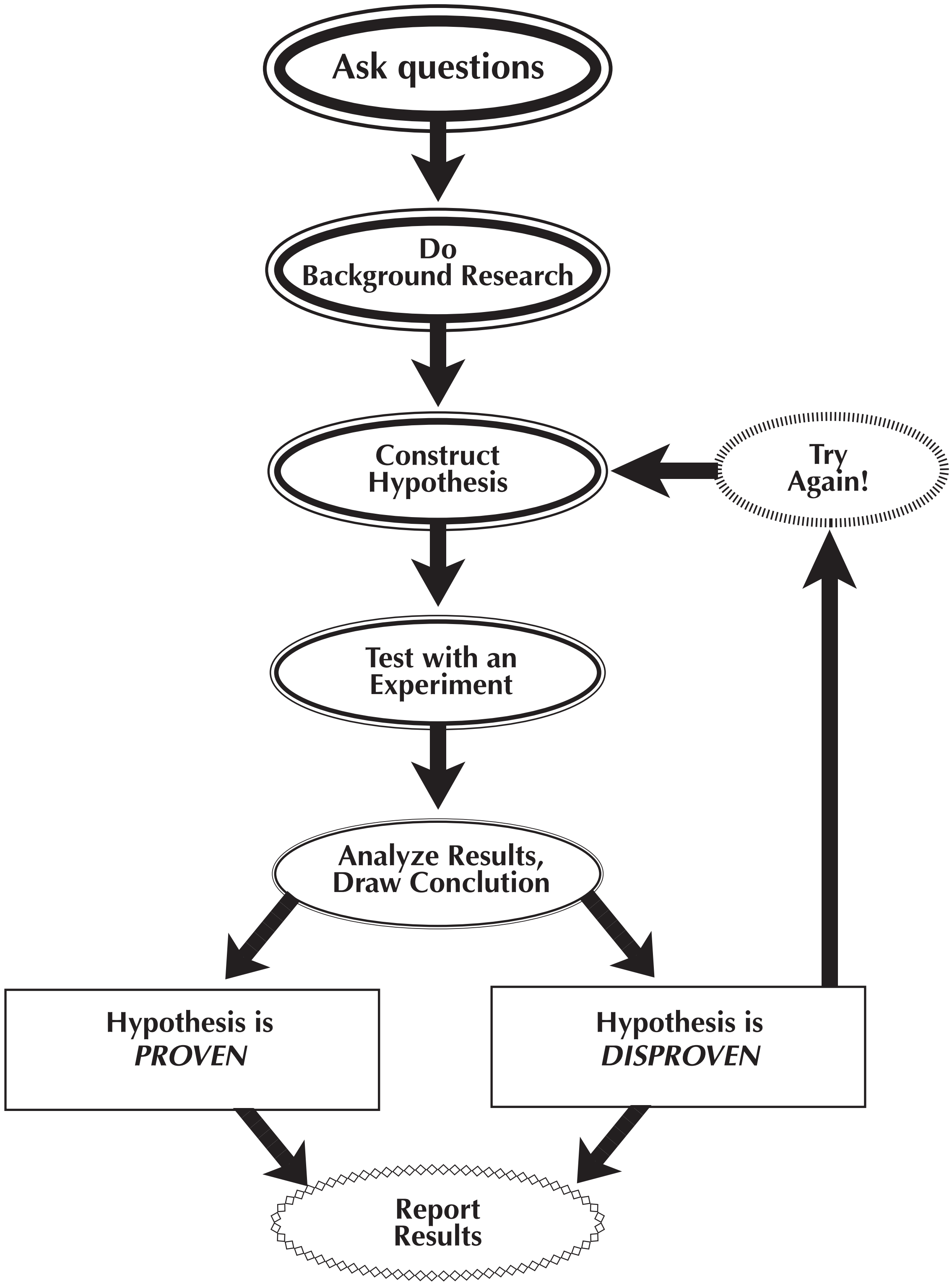
- Daily data sheets
- Lab reports
- Posters
- Journal entries

Further Enrichment

- Build on this lab to explore the effects of nitrogen on non-native and native Hawaiian plants. In general, native Hawaiian plants do not maximize nitrogen as well as non-native, opportunistic species. In this six-to-eight week long experiment, students will monitor nine pots of *ʻaʻaliʻi* or *ʻōhiʻa* seeds grown with nitrogen fertilizer, and nine pots grown without nitrogen fertilizer, comparing them to nine pots of grass seeds grown with nitrogen fertilizer and nine pots grown without nitrogen fertilizer. They will observe the effects of nitrogen on plant growth by recording days till germination and measuring the increase in biomass of each plant at the end of the experiment.

Teacher Background

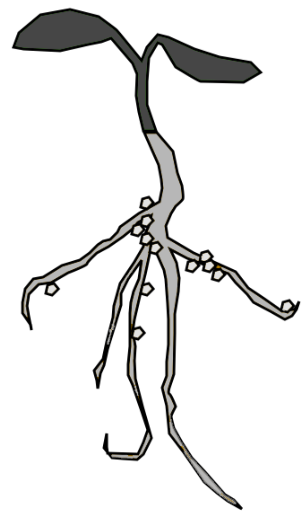
Scientific Method Chart



Nitrogen-Fixers: Friends or Foes?

Plants can't live on sunlight alone. They require many nutrients found in the soil. Nitrogen is among the primary nutrients essential to healthy plant growth. Plants need nitrogen to build proteins, nucleic acids, and DNA. The earth's atmosphere is made up of 79 percent nitrogen. Despite this abundance, most plants can't access it in its most common, gaseous form (N2).

Bacteria play an important role in harnessing atmospheric nitrogen. Bacteria are small, single-celled organisms that inhabit nearly every environment on Earth. From arctic poles to North American hot springs, these organisms can tolerate extreme environments and have many amazing capabilities. Some species of bacteria turn milk into cheese while others reproduce overnight.



With help from bacteria, some plants are able to draw nitrogen from the air. After infecting a plant, the common bacterium, *Rhizobium leguminosarum*, converts nitrogen into a usable form. *Rhizobium leguminosarum* attaches itself to the roots of the plant. It forms little growths called nodules where nitrogen is stored. Both organisms benefit from this symbiotic relationship. The bacteria receive nutrients and protection; the plant gets its fill of nitrogen. Legumes, such as peas, beans, and clover, readily form this relationship with bacteria and are known as nitrogen-fixing plants.

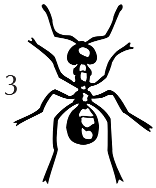
Nitrogen Fixers

Hawai'i has several native nitrogen-fixers, including *koa* in the wet forest and *wiliwili* in the dry forest. But when nonnative nitrogen-fixers appear on the scene, they can cause dramatic problems.

Myrica faya is a nitrogen-fixing tree from the North Atlantic. Introduced to Hawai'i in the late 1800s, it invades new lava flows. Under normal circumstances, plant growth on barren lava plains in Hawai'i is limited by a lack of nitrogen. It's a hot and inhospitable environment where few plants succeed. Native Hawaiian species, such as *'ōhi'a* and ferns, have evolved to endure this environment. They find footholds in the cracks where debris has collected and start the slow process of forest building.

When a bird drops a *Myrica faya* seed onto the lava, the scene quickly changes. *Myrica* can quadruple the amount of nitrogen available at a site. It captures nitrogen directly from the atmosphere and stores it in its root nodes. When the plant decomposes, nitrogen is released into the soil. Since nitrogen is natural fertilizer, its presence rolls out the welcome mat for weeds—plants that otherwise wouldn't have survived. The *'ōhi'a* and other native pioneers tend to be conservative in their use of resources such as nitrogen. They don't respond to rapid pulses or increases in nutrients, whereas weedy species capitalize on them. As a result, the natives get crowded out. Instead of endemic Hawaiian forest plants, a rag tag collection of invasives takes over the lava plain.

You will be conducting a lab to observe how plants interact with bacteria to capture airborne nitrogen.



Ecosystem Engineers Lab Report

Group Name: ______________________ *Date:* __________

1. Hypothesis (State in “If….Then” format): ______________________

2. Procedure (Control, Variable, Materials, Steps): ______________________

3. Methods of Data Analysis: ______________________

4. Results ______________________

5. Conclusion ______________________

Lab Report Guidelines

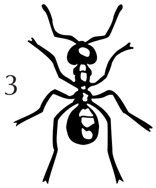
Lab reports include the following elements:

Introduction:
Background information justifying why you are testing your specific hypothesis. The introduction should end with a clear statement of your hypothesis and expectations.

Methods:
Detailed description of how your experiment was conducted. It should be detailed enough that someone else could read it and recreate your experiment.

Results and Data Analysis:
Clearly describe your results and what you did to make sense of the data. This includes talking about how and why you made each graph or table.

Conclusions:
Interpret your results and make some conclusions about your research. If no clear conclusions can be made, talk about how you could improve the experiment. Include discussion of future experiments that could be done based on the knowledge that you obtained through your experiment.



Daily Data Sheet

This data is for (circle one):

control *Rhizobium leguminosarum* nitrogen fertilizer

Date	Pot #	Number of Seedlings	Nitrogen	Height #1	Height #2	Notes	Name(s)

Activity #6

Wiliwili Gall Wasp Invasion

Length:
One class period with optional homework assignment

Prerequisite Activity:
None

Objectives:
- Trace the path of the 2005 wiliwili gall wasp invasion on Maui using real-life data.
- Identify vectors ad pathways that facilitate the spread of invasive species.
- Devise strategies for stopping an invasive pest.
- Predict the efficacy of control strategies, based on existing and plausible environmental factors.

Vocabulary:

biological control (or biocontrol)
deciduous
dormancy
Erythrina gall wasp (EGW)
vector

● ● ● Class Period One: *Exploring the Gall Wasp Invasion on Google Earth*

In Advance

This exercise requires access to Google Earth (free software available for download at www.earth.google.com) and the Wiliwili Gall Wasp Hoike.kmz file (included with this curriculum and available for download at www.hoikecurriculum.org). It's best to pre-load computers with the program and file, rather than use class time to do so.

Ideally students will work in small groups at their own computers as you lead them through the lesson, using a projector and screen. If that's not possible, a single computer and projector will suffice.

Prior to teaching the lesson, open Google Earth. If you're using the software for the first time, take a few moments to learn how zoom, pan, search, etc. using the "Navigating Google Earth" tutorial available at www.earth.google.com. It is best, though not necessary, to use Google Earth while connected to the Internet.

Explore the Wiliwili Gall Wasp Hoike.kmz file.

Provided Map Layers:
- Initial infestations (8 sites documented by Hawai'i state entomologist, Mach Fukada)
- Pu'u o Kali (best example of native *wiliwili* forest in Hawai'i and the *Erytoma erythrinae* biological control release site)

- *Wiliwili* habitat (area on Maui where native *wiliwili* trees can be found)
- Wind lines (Maui's prevailing wind directions)
- Major roads
- Ports of entry
- Agricultural land (where nonnative wiliwili trees were used as windbreaks)
- Erythrina Gall Wasp Survey (50 infected tree sites documented by the Maui Invasive Species Committee)
- Tanzania (country where state entomologist Mohsen Ramadan located the gall wasp's natural enemy: *Eurytoma erythrinae*.)

Materials & Setup

- Computer (s)
- Projector
- Wiliwili PowerPoint.ppt file (included in this curriculum or available for download on www.hear.org/hoike)
- "Wiliwili PowerPoint Script" (Teacher background, pages xx)
- Google Earth software (available for free download at www.earth.google.com)*
- Wiliwili Gall Wasp Hoike.kmz file (included in this curriculum or available for download at www.hoikecurriculum.org)*

*loaded onto each computer

Instructions

Students will trace the path of the 2005 wiliwili gall wasp invasion on Maui and respond to the challenge of controlling the pest using real-life data: wind patterns, roads, ports of entry, presence of nonnative host trees, and life cycle of the native *wiliwili*. Their task is to control the vectors to stop the gall wasp's spread.

1) Present the "Wiliwili PowerPoint" to class, using the Teacher Background "Wiliwili PowerPoint Script."

2) Homework assignment: Have students strategize how to assist the spread of *Eurytoma erythrinae*, taking the new environmental factors into account. Things to consider:
    - Non-native erythrina trees are gone and no longer serve as a breeding ground. How will this affect the speed of the spread?
      A: It will likely be slower, and not cover as much ground in residential and farming areas.
    - Which season would be best for encouraging spread?
      A: Late winter or spring, when the trees have new leaves. The period of dormancy, when there are few leaves, would not be a good choice.
    - How might heavy rain or drought affect the new wasp's spread?
      A: Rain would encourage new plant growth, which would in turn encourage gall wasp reproduction. The predatory wasp would find plenty to prey on. Drought would have the opposite effect; spread would be slower.

- Where is the best location to release the wasp?
  A: Wherever there is still a large population of Erythrina species showing signs of infection— in particular, Puʻu o Kali.
- How can each vector be incorporated into the release plan?
  - Cars can be used to intentionally transport the wasp to other areas across the island.
  - Planes and boats can be used to intentionally transport the wasp to other islands, such as Molokaʻi and Lānaʻi.
  - Wind can be taken into consideration. Biologists might choose to release wasps in a breezy area where the insects are likely to be blown to the next grove of trees.

Journal Ideas

- When the gall wasp invasion started on Maui, some people suggested eliminating the thousands of nonnative wiliwili trees to prevent them from acting as a host for the wasp. Others thought that destroying the trees was too extreme. What are your thoughts? Do you think people would have been willing to cut down their trees? Why or why not?
- Do you think eliminating the false wiliwili trees would have ultimately changed the progression of the invasion? Why or why not?
- What could Maui County or the State of Hawaiʻi do to protect itself from similar invasions in the future?
- Which elements of the wiliwili gall wasp's journey can we predict? Which elements do we have no control over?

Assessment Tools

- Answers from brainstorming session
- Participation in group discussion
- Homework assignment

Further Enrichment

- Change the elements of the gall wasp invasion; have students devise control strategies for a hypothetical insect that crawls, or is a foot long, or burrows underground.
- Have students predict the success of the introduced biological control, *Eurytoma erythrinae*, based on new factors: the elimination of the nonnative wiliwili trees as hosts, the longer lifespan of the predatory wasp, rainfall, wind direction, etc.

Teacher Background

Wiliwili PowerPoint Script

We're going to use Google Earth to explore a real-life scenario that happened on Maui in 2005. You'll have the data used by biologists and you're going to face the same challenges they did after discovering a wiliwili gall wasp invasion.

Introduce Google Earth.

[[Slide 1: screen shot of Google Earth]]
Type your school's name into the "fly to" search box in the left hand navigation bar. A list of choices will appear.

Clean up navigation box & practice navigating.

[[Slide 2: screen shot of Google Earth with arrows pointing to "fly to" box and folder listing school choices.]]
De-select the top folder, so that the checkmarks disappear. Then select your school's correct address from the list below.

Double click on the name to "fly to" your school.

Practice navigating: right and left clicks, holding and dragging mouse. Hold and drag middle roller button to tilt the view and access a horizontal plane.

Introduce Vectors

Scroll back until you can see the entire Pacific Ocean.

[[Slide 3: Earth]]
Hawai'i is the single most isolated large landmass in the world. We're almost 3,000 miles away from the nearest continent. Before humans came to these Islands, how did anything get here?
A: Wind, wings, and waves.

Now that humans are here, how do things get here?
A: Planes and boats.

These are vectors.

[[Slide 4: Vector (click several times)]]
What is a vector? It's an agent of dispersal, or a carrier that takes things from one place to another. Vectors can be living organisms, like birds; they can be natural phenomena like wind or waves; or they can be manmade modes of travel like planes and boats.

We're going to look at vectors on two scales: vectors that bring things to Hawai'i and vectors that transport them around the island once they're here.

- Have students name some vectors that move things around the island (eg: cars, wind, ocean currents, streams, birds, animals, humans, shipping containers, mail service, boats, planes, bicycles, stand up paddle boards)

Understanding vectors is important when you want to stop something from moving around. In 2005, land managers and biologists wanted to stop the *wiliwili* gall wasp.

Introduce *wiliwili*

[[slide 5: flowering wiliwili tree in Kenaio]]

- Have students pronounce Latin name: *Erythrina sandwichensis*.
- Discuss Latin name: *Erythrina* indicates genus, *sandwichensis* refers to the tree's native range, Hawai'i, once known as the Sandwich Isles.

[[slide 6: orange wiliwili flower]]
Wiliwili trees produce some of the most beautiful native Hawaiian flowers.

[[slide 7: ivory wiliwili flower]]
Flower colors can range from pale green and ivory to deep orange and red.

[[slide 8: two flowering wiliwili trees in mist]]
The *wiliwili* is a keystone species in the native Hawaiian dryland forest. Like the pillars that hold up a house, *wiliwili* trees are essential parts of this unique ecosystem's structure: they provide shelter and food for native insects and birds. They cycle water and nutrients into the soil. Shrubs and vines thrive beneath their shade.

Hawaiian cultural connections

[[slide 9: Hawaiian proverb ('ōlelo noe'au) "When the wiliwili blooms, the sharks will bite."]]
The ancient Hawaiians were excellent observers of the natural world. They recognized connections between plants, animals, and seasonal changes. According to this '*ōlelo noe'au*, or Hawaiian proverb, sharks bite when the *wiliwili* blooms. What does that mean? Anecdotal reports say that in late summer/fall, when the trees are flush with flowers, sharks are busy mating and are more active close to shore—therefore more likely to mistake a human for a snack.

[[slide 10: forceps fish]]
Hawaiians compared the color and movement of falling *wiliwili* leaves to the forceps fish. As leaves turn yellow and flutter to the ground, they resemble the native reef fish.

[[slide 11: seeds]]
The *wiliwili* tree gets its Hawaiian name from its twisted seed pods. "*Wiliwili*" means twisted.

[[slide 12: seed lei]]
Wiliwili seeds are gorgeous—ranging from dark purplish brown to scarlet. They are used to make long-lasting seed *lei* that are valuable to hula practitioners.

[[slide 13: surboards]]
The wood of the *wiliwili* tree is especially buoyant. Hawaiians used it to carve surfboards and canoe *ama*.

[[slide 14: Kenaio]]
Wiliwili trees grow in some of the world's harshest conditions: the hot, shadeless, lava plains of South Maui. They provide essential habitat for native insects and shrubs.

[[slide 15: deciduous]]
What is the word in the middle?
A: deciduous.

We don't have many deciduous plants in Hawai'i. The term refers to plants that seasonally lose their leaves, such as the New England trees famous for their fall foliage. Their leaves change color, then fall off so the trees can go dormant through the harsh winter months. These deciduous trees are regulated by temperature.

The *wiliwili* tree's deciduous cycle is regulated by moisture and is on an opposite schedule: it goes dormant during summertime. In late winter and spring, it is in full foliage, soaking up as much rainfall as it can. Then the leaves turn yellow and start to fall, resembling the forceps fish. In midsummer, the tree withdraws into itself to survive the hot, relentless summer. Then, in late summer it bursts forth in an explosion of colorful blossoms. Next, in autumn, the tree is covered in seeds. Then winter comes and the cycle starts again.

[[slide 16: stretch marks]]
Wiliwili maximize the rainy season by holding water like camels. Their trunks expand. During the dry season, the trunks shrink again, leaving stretch marks on the bark.

[[slide 17: non-native Erythrina species]]
- Ask students how many of them remember the trees lining Mokulele Highway.

People imported nonnative Erythrina species to use as windbreaks and landscaping elements. These trees were planted all over the island and played a large role in the gall wasp epidemic.

Introduce the gall wasp invasion
[[slide 18: gall wasp damage]]
These *wiliwili* leaves and stems are covered in lumpy, gnarly galls. Gall wasps are insects that lay eggs in plant tissue, causing galls to form around the developing larvae. When the larvae hatches, it eats the surrounding plant material before emerging. A mysterious gall wasp has attacked these *wiliwili* trees.

[[slide 19: gall wasp]]
- Have students say *Quadrastichus erythrinae* aloud. What does erythrinae signify?

A: a dependence on erythrina species.

[[slide 20: Discovery news article]]

- Select students to read one paragraph each aloud. (It's best if they stand up and face their classmates.) Instruct students to take out pen and paper and listen for two things in the article: 1) where the wasp came from and 2) how it is moving around on Maui.

Where did it come from?
A: It was discovered in Singapore, and in Taiwan and O'ahu, before coming to Maui.

How is it moving around on Maui?
A: wind, automobiles, shipping crates.

Work with Google Earth layers

- Return to Google Earth. Tell students to select "Queen Ka'ahumanu Mall" under "Initial Infestations. Double click to fly there.

[[slide 21: Queen K screen shot]]

- Have student read the caption.

Next select "Kahului Mall," directly below "Queen Ka'ahumanu Mall."

- Have student read caption.

- Instruct students to scroll back, for a view of all of Kahului.

- Ask them what is nearby these ports. How might a new species have arrived?

A: Kahului harbor and airport.

Select all items in the "Initial infestations" folder. These are real GPS points. Where are the two furthest points?
A. Ma'alaea and Kīhei.

Select "Pu'u o Kali" (orange square below "Initial Infestations"). Double click to fly there.

- Have student read caption.

Explore the terrain, the *pu'u*. Explain the significance of this spot—the best example of native Hawaiian dryland forest in the world.

It's your job is to protect this place from the infestation. Like the article said, you have $100,000 to respond to this emergency. The challenges: controlling the vectors. What are they? How does the wasp travel? (As students answer, instruct them to select "wind lines" "major roads" and "ports of entry" on Google Earth.)

It's your job to come up with creative, effective ideas to counteract each vector.

There's another challenge, in addition to these vectors. The large, island-wide population of nonnative erythrina trees serves as a breeding ground for the infestation. If there hadn't been any of these trees near the airport and harbor, the gall wasp would have nothing to feed on when it arrived. It very likely would have died without spreading further.

Select "ag lands." This represents the area on the island where farmers have planted nonnative erythrina trees as windbreaks.

Select "*wiliwili* habitat." This represents the area where native wiliwili trees are found growing in the wild. This area can also serve as a breeding ground for the infestation. However, wild trees grow sporadically—unlike the densely packed rows forming windbreaks around farms—so infestations here might not be as strong. Also, because native *wiliwili* trees lose their leaves during summer, they are less vulnerable to attack at that time.

Small Group Brainstorm

- Allow students to work in small groups for ten minutes. Instruct them to record their answers and choose a spokesperson to read them. After ten minutes, let each group present their ideas.

[[slide 22: solutions]]

- Discuss the solutions and why or why not they were adopted by Maui County.

Prune infested leaves and stems; compost under heavy plastic: Maui County tried this. Pruning infected trees involved renting heavy machinery, getting permission from landowners, and working overtime. Unfortunately, it failed. Biologists did not know much about the newly described wasp. They didn't know that it preferred young leaves. Pruning trees caused the infestation to spread even further.

Set up roadblocks; search cars for plant material: Maui County did not try this. It would have been extremely expensive and difficult to launch, given the time frame.

Enforce airport and seaport blockades. Maui County did not try this. It would have been extremely expensive and difficult to launch, given the time frame. (Consider discussing that baggage is inspected on the way OUT of Hawai‘i, but not on the way IN.)

Eliminate all nonnative Erythrina trees. Maui County did not try this, though it was actively considered as an option. It would have taken a massive public relations campaign to convince landowners to destroy their trees and do so without spreading infected materials.

Use pesticide. Biologists did try this. However, the inoculation cost $300 per tree, so it was only used experimentally, to preserve special trees.

Release natural enemy or biocontrol. The State of Hawai‘i did this. Immediately upon the discovery of the pest wasp, entomologists began searching the world for its natural enemies. We'll talk more about this in a bit.

Collect seeds for seed bank. The State of Hawai‘i did this. Shortly after the discovery of the gall wasp, volunteers from all over the state began collecting seeds representing genetic diversity of the species and storing them in controlled environments in the event that the tree went extinct in the wild.

[[slide 23: Efforts Fail news article]]
- Select students to read article.

[[slide 24: Dead trees on highway]]

[[slide 25: Exploded wiliwili]]
This 300-year-old native wiliwili tree in Pu‘u o Kali exploded. During the rainy season, it stored water in its trunk as usual. Later, when new leaves formed, they were attacked by gall wasps. Without a way to respirate, or release the water, the tree burst from the internal pressure.

- Instruct students to select all the items in the “MISC survey” folder on Google Earth. Inform students that while these solutions were being enacted, MISC surveyed the island to determine the extent of the infestation. Have students read captions of some of the furthest points. (eg: Lāna‘i, Nu‘u Mauka Ranch)

[[slide 26: Students Collect Seeds News Article]]
- Select students to read article.

By October of 2006, the situation was as dire as could be. Most of the nonnative erythrina species were severely infested or had already died. Around 20 percent of the trees within Pu‘u o Kali showed signs of gall wasp damage. Biologists were facing the possibility of extinction of one the key Hawaiian forest species.

Introduce Natural Enemies

[[slide 27: Mohsen Ramadan]]
Luckily, students weren’t the only ones working to save the wiliwili. State entomologist Mohsen Ramadan was researching the gall wasp, *Quadrastichus erythrinae*. Very little was known about the pest. It had been discovered in Singapore, but it was an invasive pest there, too. No one knew where its true origin was, or how to control it. Because *Quadrastichus* was dependent on erythrina species for survival, Mohsen looked to the highest population of erythrina species in the world: Africa. While Hawai‘i has one native erythrina species, East Africa has numerous. The State of Hawai‘i sent Mohsen to Tanzania to search for natural enemies of the gall wasp.

- Instruct students to select “Tanzania.” Double click to fly there.

[[slide 28: Eurytoma erythrinae]]
Mohsen traveled through Tanzania by bus, stopping in the countryside to inspect trees for signs of gall wasp. He was successful. He found *Quadrastichus erythrinae* and several natural enemies. The most promising was another wasp.

- Have students say: *Eurytoma erythrinae*. Ask them what *erythrinae* signifies.

A: the wasp is dependent on *Erythrina* species—in this case, the *Erythrina* gall wasp.

Eurytoma erythrinae wasps lay their eggs inside the *Quadrastichus erythrinae* galls. *Eurytoma erythrinae* larvae hatch first and feed on *Quadrastichus erythrinae* larvae.

The State of Hawai‘i subjected *Eurytoma erythrinae* to numerous tests to insure it wouldn't become a new pest. When biologists were ready to release it, they were confronted with a new problem—the opposite of their first challenge—how to help the wasp spread far and fast.

- Instruct students to select "Pu‘u o Kali." Double click to fly there.

[[slide 29: Test tube release of Eurytoma erythrinae]]
Hawai‘i Department of Agriculture entomologists released *Eurytoma erythrinae* on infected trees in Pu'u O Kali in November 2008. It immediately began attacking *Quadrastichus erythrinae*, slowing the infestation down considerably.

[[slide 30: Wiliwili seeds germinating in lava]]
Galls were still found on trees, but instead of crippling the tree, they were only present in small numbers. Germinating seeds, like these two, stood a good chance of developing into future trees.

[[slide 31: Rainbow over wiliwili habitat]]
By 2011, scientists had declared the effort a success. If you'd like to enjoy the spectacular blooming wiliwili, take a drive out to Kaupō in late summer. Along the roadside you'll find trees awash in cream-colored and red blossoms.

[[slide 32: wiliwili in flower]]